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ABSTRACT

Proper installation, inspection, operation, maintenance, repair and management of water distribution systems have a significant impact on the operation and maintenance cost and effectiveness of the systems. The objective of this manual is to provide water distribution system operators with the knowledge and skills required to operate and maintain water systems effectively. This manual was developed to serve as a home-study or self-paced instructional course. The document contains information on: (1) what water distribution operators do; (2) procedures for operating and maintaining clear wells and storage tanks; (3) characteristics of distribution system facilities; (4) how to operate and maintain distribution facilities; (5) how to maintain water quality in distribution systems; (6) disinfection of new and repaired facilities as well as water delivered to consumers; and (7) techniques for recognizing hazards and developing safe procedures and safety programs. The appendices include a trial final examination (with answers), tips on solving water distribution system arithmetic problemS, water abbreviations, a glossary of water words, and subject index. (TW)

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This training manual has been reviewed by the Office of Drinking Water, U.S. Environmental Protection Agency and the California Department of Health Services. Both agencies have approved this manual for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency nor the California Department of Health Services. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency; California Department of Health Services; California State University, Sacramento; National Environmental Training Association; authors of the chapters or project reviewers, consultants, and directors.

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WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

Second Edition
A Field Study Training Program

prepared by

California State University, Sacramento
School of Engineering
Applied Research and Design Center

in cooperation with the
National Environmental Training Association

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Kenneth D. Kerri, Project Director

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for the

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OPERATOR TRAINING MANUALS IN THIS SERIES are available from Ken Kerri, California State University, 6000 J Street, Sacramento, CA 95819-2694, phone (916) 278-6142:

1. *SMALL WATER SYSTEM OPERATION AND MAINTENANCE,*
2. *WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE,*
3. *WATER TREATMENT PLANT OPERATION,* 2 volumes,
4. *OPERATION OF WASTEWATER TREATMENT PLANTS,* 4 Volumes, and
5. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS,* 2 Volumes.

NOTICE

This manual is revised and updated before each printing based on comments from persons using this manual.

FIRST EDITION - **WATER SUPPLY SYSTEM OPERATION**

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SECOND EDITION - **WATER DISTRIBUTION SYSTEM O & M**

FIRST PRINTING, 1987 7,000

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PREFACE TO THE FIRST EDITION

The purposes of this water supply system field study training program are to:

1. Develop new qualified water supply system operators,
2. Expand the abilities of existing operators, permitting better service to both their employers and the public, and
3. Prepare operators for civil service and *CERTIFICATION EXAMINATIONS.*[1]

To provide you with the knowledge and skills needed to operate and maintain water supply systems as efficiently and effectively as possible, experienced water supply system operators prepared the material in each chapter of this manual.

Water supply systems vary from city to city and from region to region. The material contained in this program is presented to provide you with an understanding of the basic operation and maintenance aspects of your system and with information to help you analyze and solve operation and maintenance problems. This information will help you operate and maintain your system in a safe and efficient manner.

Water supply operation and maintenance is a rapidly advancing field. To keep pace with scientific and technological advances, the material in this manual must be periodically revised and updated. *THIS MEANS THAT YOU, THE OPERATOR, MUST RECOGNIZE THE NEED TO BE AWARE OF NEW ADVANCES AND THE NEED FOR CONTINUOUS TRAINING BEYOND THIS PROGRAM.*

BASIC TRAINING • ADVANCED TRAINING • CERTIFICATION EXAMINATION

The Project Director is indebted to the many operators and other persons who contributed to this manual. Every effort was made to acknowledge material from the many excellent references in the water supply field. Reviewers Leonard Ainsworth, Jack Rossum, and Joe Monscvitz deserve special recognition for their extremely thorough review and helpful suggestions. John Trax, Chet Pauls, and Ken Hay, Office of Drinking Water, U.S. Environmental Protection Agency, and John Gaston, Bill MacPherson, Bert Ellsworth, Clarence Young, Ted Bakker, and Beverlie Vandre, Sanitary Engineering Branch, California Department of Health Services, all performed outstanding jobs as resource persons, consultants and advisers. Larry Hannah served as Educational Consultant. Illustrations were drawn by Martin Garrity. Charlene Arora helped type the field test and final manuscript for printing. Special thanks are well deserved by the Program Administrator, Gay Kornweibel, who typed, administered the field test, managed the office, administered the budget, and did everything else that had to be done to complete this project successfully.

KENNETH D. KERRI
PROJECT DIRECTOR

1983

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[1] *Certification examination. An examination administered by a state or professional association that water supply system operators take to indicate a level of professional competence. In many states certification of water supply system operators is voluntary. Current trends indicate that more states and employers will require water supply system operators to be "certified" in the future.*

PREFACE TO THE SECOND EDITION

WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE is the title of this portion of the Second Edition. When the First Edition, **WATER SUPPLY SYSTEM OPERATION,** was developed, the objective was to produce one comprehensive training manual for water supply system operators. The resulting manual covered all aspects of water supply systems from the source of the water supply to the consumer's tap.

Operators using the First Edition, **WATER SUPPLY SYSTEM OPERATION,** expressed a valid concern that too much material was covered in one training manual. In response to this concern the manual was split approximately in half to produce the Second Edition as two manuals:

- **WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE**, and
- **SMALL WATER SYSTEM OPERATION AND MAINTENANCE.**

WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE describes the responsibilities of being an operator, storage facilities, distribution systems, water quality considerations, distribution system operation and maintenance, disinfection and safety. **SMALL WATER SYSTEM OPERATION AND MAINTENANCE** contains information on the responsibilities of being an operator, water sources, wells, small water treatment plants, disinfection, safety, lab procedures and a new chapter on rates. The chapters on disinfection and safety are in both manuals because of their extreme importance. Both of these operator training manuals are equally important if you are responsible for a water supply system. If your agency is large enough to employ two or more crews of operators, the crews may specialize in a particular aspect of operation and maintenance. For example, one crew may deal primarily with wells and disinfection, while the other crew is assigned the responsibility of the distribution system. The splitting of the original manual, **WATER SUPPLY SYSTEM OPERATION,** into two manuals will allow operators to concentrate their studies on the subject areas related directly to their jobs. At the same time, it is hoped that operators will realize the importance of understanding all aspects of water supply systems and attempt to complete both of the manuals.

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1987

OBJECTIVES OF THIS MANUAL

Proper installation, inspection, operation, maintenance, repair, and management of water distribution systems have a significant impact on the operation and maintenance costs and effectiveness of the systems. The objective of this manual is to provide water distribution system operators with the knowledge and skills required to operate and maintain water systems effectively, thus eliminating or reducing the following problems:

1. Health hazards created by the delivery of unsafe water to the consumer's tap;
2. System failures that result from the lack of proper installation, inspection, preventive maintenance, surveillance and repair programs designed to protect the public investment in these facilities;
3. Tastes and odors caused by water distribution system problems;
4. Corrosion damages to pipes, equipment, tanks and structures in the water distribution system;
5. Complaints from the public or local officials due to the unreliability or failure of the water distribution system to perform as designed; and
6. Fire damage caused by insufficient water and/or inadequate pressures at a time of need.

SCOPE OF THIS MANUAL

Operators with the responsibility for water storage and distribution systems will find this manual very helpful. This manual contains information on:

1. What water distribution system operators do,
2. Procedures for operating and maintaining clear wells and storage tanks,
3. Characteristics of distribution system facilities,
4. How to operate and maintain distribution systems,
5. How to maintain water quality in distribution systems,
6. Disinfection of new and repaired facilities as well as water delivered to consumers, and
7. Techniques for recognizing hazards and developing safe procedures and safety programs.

Material in this manual furnishes you with information concerning situations encountered by most water distribution system operators in most areas. These materials provide you with an understanding of the basic operational and maintenance concepts for water distribution systems and with an ability to analyze and solve problems when they occur. Operation and maintenance programs for water distribution systems will vary with the age of the system, the extent and effectiveness of previous programs, and local conditions. You will have to adapt the information and procedures in this manual to your particular situation.

Technology is advancing very rapidly in the field of operation and maintenance of water distribution systems. To keep pace with scientific advances, the material in this program must be periodically revised and updated. This means that you, the water distribution system operator, must be aware of new advances and recognize the need for continuous personal training reaching beyond this program.

TRAINING OPPORTUNITIES EXIST IN YOUR DAILY WORK EXPERIENCE, FROM YOUR ASSOCIATES, AND FROM ATTENDING MEETINGS, WORKSHOPS, CONFERENCES AND CLASSES.

TECHNOLOGY

USES OF THIS MANUAL

This manual was developed to serve the needs of operators in several different situations. The format used was developed to serve as a home-study or self-paced instruction course for operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program uses the concepts of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person has successfully completed this program, an objective test is included at the end of each chapter.

Also, this manual can serve effectively as a textbook in the classroom. Many colleges and universities have used similar manuals as texts in formal classes (often taught by operators). In areas where colleges are not available or are unable to offer classes in the operation of water distribution systems, operators and utility agencies can join together to offer their own courses using the manual.

Cities or utility agencies can use the manual in several types of on-the-job training programs. In one type of program, a manual is purchased for each operator. A senior operator or a group of operators are designated as instructors. These operators help answer questions when the persons in the training program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach eliminates any waiting while papers are being graded and returned by CSUS.

This manual was prepared to help operators operate and maintain their water distribution systems. Please feel free to use the manual in the manner which best fits your training needs and the needs of other operators. We will be happy to work with you to assist you in developing your training program. Please feel free to contact

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INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example, many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in seven chapters. Some chapters are longer and more difficult than others. For this reason, many of the chapters are divided into two or more lessons. The time required to complete a lesson will depend on your background and experience. Some people might require an hour to complete a lesson and some might require three hours; but that is perfectly all right. ***THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!***

Each lesson is arranged for you to read a short section, write the answers to the questions at the end of the section, check your answers against suggested answers; and then *YOU* decide if you understand the material sufficiently to continue or whether you should read the section again. You will find that this procedure is slower than reading a normal textbook, but you will remember much more when you have finished the lesson.

At the end of each chapter, you will find an "objective test." Mark your answers on the special answer sheet provided for each chapter. Some discussion and review questions are provided following each lesson in the later chapters. These questions review the important points you have covered in the lesson.

The objective test at the end of each lesson contains true or false, multiple-choice, fill-in-the-blank, or match-the-answers types of questions. The purposes of this exam are to review the chapter and to give experience in taking different types of exams. *MAIL TO THE PROGRAM DIRECTOR ONLY YOUR ANSWERS TO OBJECTIVE TESTS ON THE PROVIDED ANSWER SHEETS.*

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remember the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states for higher-level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next certification or civil service examination.

You are your own teacher in this program. You could merely look up the suggested answers from the answer sheet or copy them from someone else, but you would not understand the material. Consequently, you would not be able to apply the material to the operation of your facilities nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.

SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn in each chapter (the chapter objectives).
2. Read sections in the lesson.
3. Write your answers to questions at the end of each section in your notebook. You should write the answers to the questions just as you would if these were questions on a test.
4. Check your answers with the suggested answers.
5. Decide whether to reread the section or to continue with the next section.
6. Write your answers to the discussion and review questions at the end of each lesson in your notebook.
7. Mark your answers to the objective test on the answer sheet provided by the Project Director or by your instructor.

8. Mail material to the Project Director. (Send *ONLY* your completed answer sheet.)

Ken Kerri, Project Director
Water Supply System Operation
California State University, Sacramento
6000 J Street
Sacramento, California 95819

B. PROJECT DIRECTOR

1. Mails answer sheet for each chapter to operator.
2. Corrects tests, answers any questions, and returns results to operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the lessons. You may proceed in numerical order, or you may wish to work some lessons sooner.

SAFETY IS A VERY IMPORTANT TOPIC. Everyone working in a water distribution system must always be safety conscious. Operators daily encounter situations and equipment that can cause a serious disabling injury or illness if the operator is not aware of the potential danger and does not exercise adequate precautions. For these reasons, you may decide to work on Chapter 7, "Safety" early in your studies. In each chapter, SAFE PROCEDURES ARE ALWAYS STRESSED.

THINK SAFETY!

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COURSE OUTLINE

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COURSE OUTLINE

SMALL WATER SYSTEM OPERATION AND MAINTENANCE

(Wells, Small Treatment Plants, and Rates)

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CHAPTER 1

THE WATER DISTRIBUTION SYSTEM OPERATOR

by

Ken Kerri

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OBJECTIVES

Chapter 1. THE WATER DISTRIBUTION SYSTEM OPERATOR

At the beginning of each chapter in this manual you will find a list of OBJECTIVES. The purpose of this list is to stress those topics in the chapter that are most important. Contained in the list will be items you need to know and skills you must develop to operate, maintain, repair and manage a water distribution system as efficiently and as safely as possible.

Following completion of Chapter 1, you should be able to:

1. Explain the type of work done by water distribution system operators.
2. Describe where to look for jobs in this profession, and
3. Find sources of further information on how to do the jobs performed by water distribution system operators.

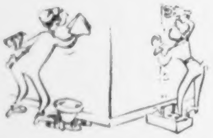
CHAPTER 1. THE WATER DISTRIBUTION SYSTEM OPERATOR

Chapter 1 is prepared especially for new operators or people interested in becoming water distribution system operators. If you are an experienced water distribution system operator, you may find some new viewpoints in this chapter.

In these training manuals the water supply system has been divided into two parts: (1) the water system and (2) the water distribution system. The water system begins with the source of water such as groundwater or surface water. Wells, pumps and treatment facilities are part of the water system which delivers water to the distribution system. The water distribution system consists of tanks and pipes which store and deliver treated water to consumers.

1.0 NEED FOR WATER DISTRIBUTION SYSTEM OPERATORS

People need safe and pleaseant water to drink. Many sources of water are not directly suitable for drinking purposes. Engineers have designed water supply facilities to collect, store, transport, treat and distribute water to people and industries. Once these facilities are built, the operators make the facilities do their intended job. Water distribution system operators operate, maintain, repair and manage these facilities. Operators have the responsibility of insuring that safe and pleasant drinking water is delivered to everyone's tap. Another responsibility is to be sure that adequate amounts of water and pressure are available during times of emergency, such as a fire. Cities and towns need qualified, capable, and dedicated operators to do these jobs.



The need for *RESPONSIBLE* water distribution system operators cannot be overstressed. You, as a water distribution system operator, have the responsibility for the health and well being of the community you serve. Yes, you are responsible for the drinking water of your community and anytime you fail to do your job, you could be responsible for an outbreak of a water-borne disease which could even result in death. As an operator, you do not want the knowledge that you were negligent in your duty and, as a result, were responsible for the death of a fellow human being.

QUESTIONS

Below are some questions for you to answer. You should have a notebook in which you can write the answers to the questions. By writing down the answers to the questions, you are helping yourself learn and retain the information. After you have answered all the questions, compare your answers with those given in the Suggested Answers section on page 10. Reread any sections you do not understand and then proceed to the next section. You are your own teacher in this training program, and *YOU* should decide when you understand the material and are ready to continue with new material.

1.0A What is the responsibility of water distribution system operators?

1.0B What do water distribution system operators do with water distribution facilities?

1.1 WHAT IS A WATER SUPPLY SYSTEM?

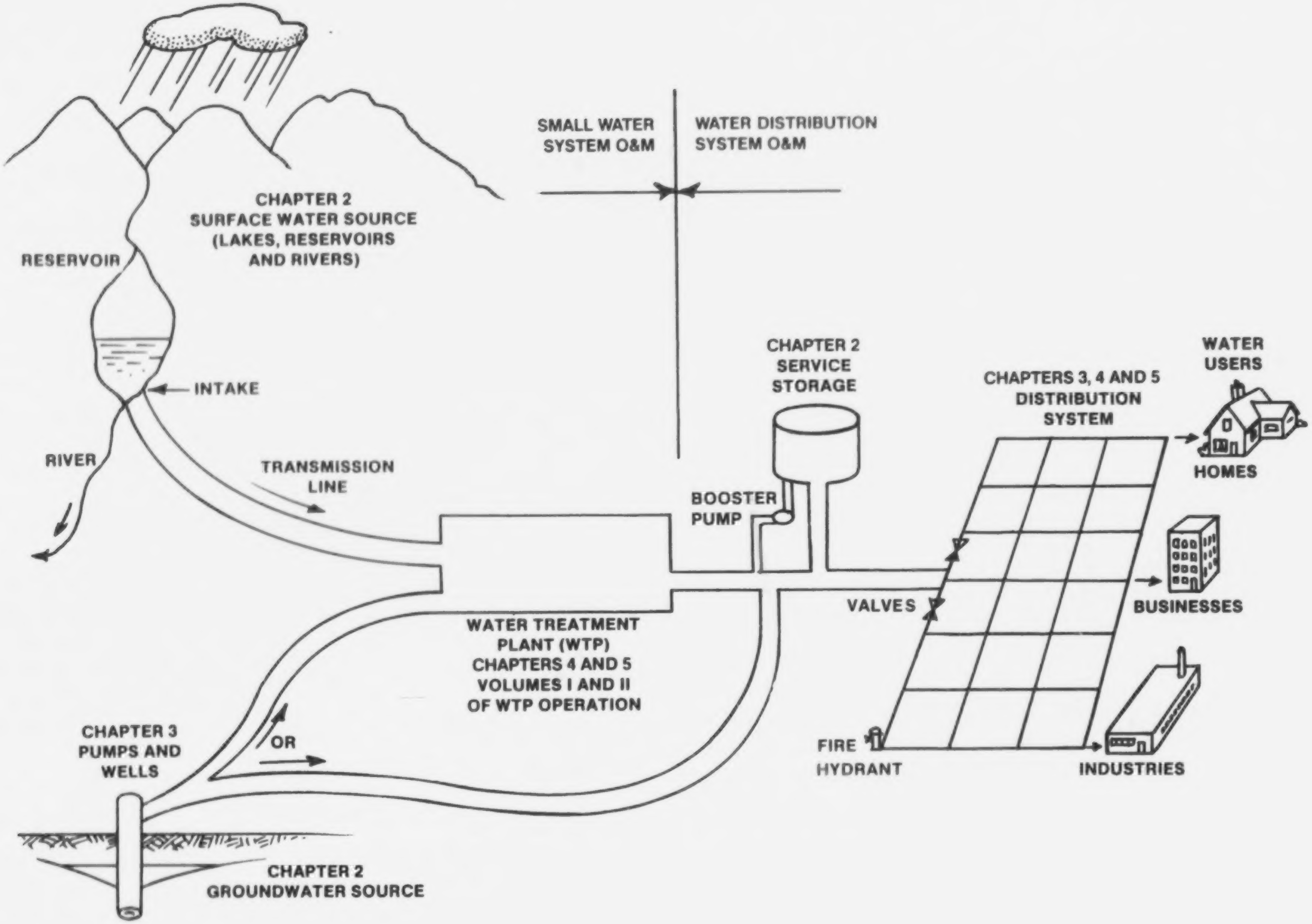
1.10 Sources of Water

A water supply system delivers water from its source to the ultimate consumer — homes, businesses or industrial water users (Fig. 1.1). The source of a water supply may be either groundwater or surface waters. Surface waters may be natural lakes, streams, rivers or reservoirs behind dams. Groundwater is a water source below the ground surface.

Water is usually transported from its source through a transmission system consisting of either open channels (canals) or large-diameter pipes (called raw water conduits) to the water treatment plant. After treatment the water is usually pumped into transmission lines which are connected to a distribution grid system. From the grid system the water is delivered to individual service lines which serve private homes, businesses, factories and industries. Groundwaters may not have transmission lines, but are often disinfected with chlorine and pumped directly to service storage and distribution systems.

1.11 Storage Facilities

Storage facilities may consist of large reservoirs behind dams (impoundments) or service storage reservoirs located at water treatment plants and/or at various places in distribution systems. Storage facilities for treated water at water treatment plants are called clear wells. Operational service storage tanks in distribution systems may be pressure tanks, elevated tanks, ground-level tanks or reservoirs, or underground facilities.


SMALL WATER SYSTEM O&M
WATER DISTRIBUTION SYSTEM O&M
CHAPTER 2 SURFACE WATER SOURCE (LAKES, RESERVOIRS AND RIVERS)
RESERVOIR
INTAKE
RIVER
TRANSMISSION LINE
CHAPTER 2 SERVICE STORAGE
BOOSTER PUMP
WATER USERS
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HOMES
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CHAPTER 3 PUMPS AND WELLS
OR
FIRE HYDRANT
INDUSTRIES
CHAPTER 2 GROUNDWATER SOURCE

Fig. 1.1 Typical water supply system

1.12 Treatment Facilities

Surface waters require treatment to remove suspended and dissolved materials and also to kill disease-causing organisms. Groundwater may require treatment for the removal of excessive hardness, taste- and odor-causing substances, dissolved gases, and impurities such as iron and manganese. Water treatment plants provide the necessary treatment to make the waters safe and suitable for drinking purposes. All waters, regardless of source or treatment received, should be disinfected to prevent the spread of disease-causing organisms. Chlorination is the most common means of disinfection used today to protect the public's health.

1.13 Distribution Systems

A distribution system consists of a network of pipes, valves, fire hydrants, service lines, meters, and pumping stations. The system delivers water to homes, businesses and industries for drinking and other uses. This water also is used for fire protection. The network of pipes, pumping stations, and service storage reservoirs must have sufficient capacity to meet maximum water demands plus fire-fighting requirements and still maintain adequate water pressures throughout the water distribution system. Valves are necessary to isolate portions of the distribution system for cleaning, maintenance, repairs, and making additions to the system. The distribution system should be free of cross-connections with unapproved water supplies which could allow contamination to be introduced into the system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 10.

1.1A List the two major sources of water supplies.

1.1B Why should surface waters be treated?

1.2 WHAT DOES A WATER DISTRIBUTION SYSTEM OPERATOR DO?

1.20 Operation and Maintenance

Simply described, water distribution system operators keep the system operating efficiently to deliver safe and pleasant water. They inspect the system to keep the water flowing today and in the future. Physically, they have manual and power-operated equipment to help them do the job, including repairs and minor additions to the system. Other jobs include lubricating and maintaining equipment, collecting water samples and recordkeeping. Typical duties performed by water distribution system operators are summarized in Table 1.1

To describe your duties in detail, let's start at the beginning. Let us say that the need for new wells and pumps, and also for new or improved storage tanks and distribution pipe network has long been recognized by your community. The community has voted to issue the necessary bonds to finance the project, and the consulting engineers have been requested to submit plans and specifications. In the best interests of the community and the consulting engineer, you should be in on the ground floor planning and design.

You and the engineer should discuss the proposed locations and layout of wells, service reservoirs and pipe networks. Your job is to discuss with the engineer how these new facilities could be operated, maintained and repaired and also to make suggestions on how these jobs could be done more easily. Be sure there is adequate room for maintenance and repair equipment even during adverse weather conditions. Together with the consulting engineers, you can be a member of an expert team able to advise your water utility.

TABLE 1.1 TYPICAL DUTIES OF A WATER DISTRIBUTION SYSTEM OPERATOR

1. Place barricades, signs, and traffic cones around work sites to protect operators and public.
2. Excavate trenches and install shoring.
3. Lay, connect, test and disinfect water mains.
4. Tap into water mains.
5. Flush and clean water mains.
6. Read and update water distribution system maps and "as built" plans.
7. Operate and maintain well pumps and hydropneumatic pressure tanks.
8. Collect and transport water samples.
9. Clean and disinfect storage tanks and reservoirs.
10. Protect water mains and storage facilities from corrosion effects.
11. Observe pump motors to detect unusual noises, vibrations, or excessive heat.
12. Adjust and clean pump seals and packing glands and also clean mechanical seals.
13. Repair and overhaul pumps, motors, chlorinators, and control valves.
14. Safely load and unload chlorine cylinders and other dry and liquid chemicals.
15. Keep records and prepare reports.
16. Estimate and justify budget requests for supplies and equipment.
17. Start up or shut down pumps as necessary to regulate system flows and pressures.
18. Perform efficiency tests on pumps and related equipment.
19. Troubleshoot minor electrical and mechanical equipment problems and correct.
20. Detect hazardous atmospheres and correct before entry.
21. Conduct safety inspections, follow safety rules for waterworks facilities, and also develop and conduct tailgate safety meetings.
22. Troubleshoot to locate the causes of water quality complaints.
23. Discuss with the public their concerns regarding the quality of the water they receive.
24. Communicate effectively with other operators and supervisors on the technical level expected for your position.

Ultimately you want to operate your pumps and reservoirs in such a fashion that your consumers will always have sufficient, safe and pleasant water at adequate pressures.

1.21 Supervision and Administration

In addition to operation and maintenance duties for your water distribution system, you may also be responsible for supervision and personnel. Chief operators or supervisors frequently have the responsibility of training new operators and should encourage all operators to strive for higher levels of certification.

As a water distribution administrator, you may be in charge of recordkeeping. In this case, you will be responsible for operating and maintaining the system as efficiently as possible, keeping in mind that the primary objective is to deliver safe and pleasant drinking water to your consumers. Without adequate, reliable records of important phases of operation and maintenance, the effectiveness of your operation has not been documented (recorded). Also, accurate records are required by regulatory agencies in accordance with the Drinking Water Regulations of the Safe Drinking Water Act.

You may also be the budget administrator. Here you will be in the best position to give advice on budget requirements, management problems, and future planning. You should be aware of the necessity for additional expenditures, including funds for new facilities and enlargement of existing facilities, equipment replacement, and additional employees. You should recognize these and define them clearly for the proper officials. Early planning and budgeting of this type will contribute greatly to the continued smooth operation of your facility.

1.22 Public Relations

As an operator you are in the field of public relations and must be able to explain the purpose and operation of your facilities to civic organizations, school classes, representatives of news media, and even to city council members or directors of your district. Lots of people want to know about the large elevated storage tank or those "funny things" sticking out the top of an underground storage reservoir. One of the best results from a well-guided tour is gaining support from your city council and the public to obtain the funds necessary to run a good operation.

The overall appearance of your pump stations and elevated tanks indicates to the public the type of operation you maintain. If the facilities are dirty and rundown, in need of painting, and overgrown with weeds, you will be unable to convince the public that you are doing a good job. *YOUR RECORDS SHOWING THAT YOU ARE DELIVERING SAFE DRINKING WATER TO YOUR CONSUMERS WILL MEAN NOTHING TO VISITORS AND NEIGHBORS OF YOUR FACILITIES UNLESS YOUR FACILITIES APPEAR CLEAN AND WELL MAINTAINED.*

Another aspect of your job may be handling complaints. When someone contacts you complaining that their drinking water looks muddy, tastes bad or smells bad, you may have a serious problem. Whenever someone complains, record all of the necessary information (name, date, location, and phone number) and have the complaint thoroughly investigated. Be sure to notify the person who complained of the results of your investigation and what corrective action was or will be taken.

SAFETY FIRST!
WATCH YOUR STEP!
Think Safety
IF IN DOUBT DON'T!
SAFETY

1.23 Safety

Safety is a very important operator responsibility. Unfortunately, too many water distribution system operators take safety for granted. *YOU* have the responsibility to be sure that your facilities are a safe place to work and that everyone follows safe procedures. Everyone must follow safe procedures and understand why safe procedures must be followed at all times. All operators must be aware of safety hazards in and around water distribution facilities. Work in traffic and excavating for the installation or repair of pipes can be extremely hazardous. Explosive conditions can develop when painting the inside of an elevated tank if adequate ventilation is not provided. Most accidents result from carelessness or negligence. You should plan or be a part of an active safety program. Also, you may have the responsibility of training new operators and safe procedures must be stressed.

Clearly, the modern day water distribution system operator must be capable of doing many jobs — *AND DOING THEM ALL SAFELY.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 10.

1.2A Why should water distribution system operators discuss proposed facilities with engineers?

1.2B Why are adequate and reliable records very important?

1.2C To whom might you have to explain the purpose and operation of your facilities?

1.2D Why is the appearance of pump stations and elevated tanks and the grounds around them important?

1.2E Why is safety important?

1.3 JOB OPPORTUNITIES

1.30 Manpower Needs

The water distribution system field is changing rapidly. New facilities and systems are being constructed, and old facilities and systems are being modified and enlarged to meet the water distribution demands of our growing population and industries. Towns, municipalities, special districts and industries all employ water distribution system operators. Operators, maintenance personnel, foremen, managers, instrumentation experts, and laboratory technicians are sorely needed now and will be in the future.

1.31 Who Hires Water Distribution System Operators?

Operators' paychecks usually come from a city, water agency or district, or a private utility company. The operator also may be employed by one of the many large industries which operate their own water distribution system. As an operator, you are always responsible to your employer for operating and maintaining an economical and efficient water distribution system. An even greater obligation rests with the operator because of the great number of people who drink the water from the distribution system. In the final analysis, the operator is really working for the people who depend on the operator to provide them with safe and pleasant drinking water.

1.32 Where Do Water Distribution System Operators Work?

Jobs are available for water distribution system operators wherever people live and need someone to deliver water to their homes, offices or industrial processes. The different types and locations of water distribution systems offer a wide range of working conditions. From the mountains to the sea, wherever people gather together into communities, water distribution systems will be found. From a distribution system foreman or a computer control center operator at a complex municipal storage and distribution system to a one-person manager of a small town water distribution system, you can select your own special place in water distribution system operation.

1.33 What Pay Can a Water Distribution Operator Expect?

In dollars? Prestige? Job satisfaction? Community service? In opportunities for advancement? By whatever scale you use, returns are mainly what you make them. If you choose a large municipality, the pay is good and advancement prospects are tops. Choose a small town and the pay may not be as good, but job satisfaction, freedom from time-clock hours, community service, and prestige may well add up to a more desirable outstanding personal achievement. If you have the ability and take advantage of the opportunities, you can make this field your career and advance to an enviable position. Many of these positions are or will be represented by an employee organization that will try to obtain higher pay and other benefits for you. Total reward depends on you and how *YOU APPLY YOURSELF.*

Satisfaction
Prestige
DOLLARS
COMMUNITY SERVICES
Advancement
OPPORTUNITIES

1.34 What Does it Take To Be a Water Distribution System Operator?

DESIRE. First you must make the serious decision to enter this fine profession. You can do this with a high school or a college education. While some jobs will always exist for manual labor, the real and expanding need is for *QUALIFIED OPERATORS.* You must be willing to study and take an active role in upgrading your capabilities. New techniques, advanced equipment, and increasing use of complex instrumentation and computers require a new breed of water distribution system operator; one who is willing to learn today, and gain tomorrow, for surely your water distribution system will move towards newer and more effective operation and maintenance procedures. Indeed, the truly service-minded operator assists in adding to and improving the performance of the water distribution system on a continuing basis.

You can be a water distribution system operator tomorrow by beginning your learning today; or you can be a better operator, ready for advancement, by accelerating your learning today.

This training course, then, is your start towards a better tomorrow, both for you and for the public who will receive better water from your efforts.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 10.

1.3A Who hires water distribution system operators?

1.3B What does it take to be a good water distribution system operator?

1.4 PREPARING YOURSELF FOR THE FUTURE

1.40 Your qualifications

What do you know about your job or the job you'd like to obtain? Perhaps a little, and perhaps a lot. You must evaluate the knowledge, skills and experience you already have and what you will need to achieve future jobs and advancement.

The knowledge and skills required for your job depend to a large degree on the size and type of water distribution system where you work. You may work on a large, complex system serving several hundred thousand persons and employing a hundred or more operators. In this case, you are propably a specialist in one or more phases of the distribution system or storage reservoirs (such as being responsible for the valves).

On the other hand, you may operate and maintain a small water distribution system serving only a thousand people or even fewer. You may be the only operator, for the entire system or, at best, have only one or two helpers. If this is the case, you must be a "jack-of-all-trades" because of the diversity of your tasks.

1.41 Your Personal Training Program

Beginning on this page you are starting a training course which has been carefully prepared to help you to improve your knowledge and skills to operate and maintain water distribution systems.

You will be able to proceed at your own pace; you will have the opportunity to learn a little or a lot about each topic. This training manual has been prepared this way to meet the various needs of water distribution system operators, depending on the size and type of system for which you are responsible. To study for certification and civil service exams, you may have to cover most of the material in this manual. You will never know everything about water distribution systems and the equipment and procedures available for operation and maintenance. However, you will be able to answer some very important questions about how, why, and when certain things happen in water distribution systems. You can also learn how to manage your water distribution system to provide a reliable supply of safe and pleasant drinking water to your customers while minimizing costs in the long run.

This training course is not the only one available to help you improve your abilities. Some state water utility associations, vocational schools, community colleges, and universities offer training courses on both a short- and long-term basis. Many state, local and private agencies have conducted training programs and informative seminars. Most state health departments can be very helpful in providing training programs or directing you to good programs.

Some libraries can provide you with useful journals and books on water distribution systems. Listed below are several very good references in the field of water distribution systems. Prices listed were those available when this manual was published; they will probably increase in the future.

1. *A MANUAL OF INSTRUCTION FOR WATER TREATMENT PLANT OPERATORS.* Available from Health Education Service, Inc., P. O. Box 7126, Albany, New York 12224. Price $3.13.
2. *MANUAL OF WATER UTILITY OPERATIONS.* Available from Texas Water Utilities Association, 6521 Burnet Lane, Austin, Texas 79757. Price $17.00.
3. *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK,* Order No. 20103. Available from Computer Services, American Water Works Association, 6666 W. Quincy Avenue, Denver, Colorado 80235. Price to Members, $13.00; Nonmembers, $16.50.
4. *INTRODUCTION TO WATER SOURCES AND TRANSMISSION,* Volume I. Order No. 1901. Available from Computer Services, American Water Works Association, 6666 W. Quincy Avenue, Denver, Colorado 80235. Price $10.00.
5. *INTRODUCTION TO WATER DISTRIBUTION,* Volume 3, Order No. 1916. Available from Computer Services, American Water Works Association, 6666 W. Quincy Avenue, Denver, Colorado 80235. Price, $27.50.
6. *STUDY GUIDE TO THE ABC TESTING SERVICE FOR WATER TREATMENT PLANT AND DISTRIBUTION SYSTEM OPERATORS.* Association of Boards of Certification (ABC), P. O. Box 2266, Ames, Iowa 50010. Price $14.00.

Throughout this manual we will be recommending American Water Works (AWWA) publications. Members of AWWA can buy some publications at reduced prices. You can join AWWA by writing to the headquarters office in Denver or by contacting a member of AWWA. Headquarters can help you contact your own state or regional AWWA Section. This professional organization can offer you many helpful training opportunities and educational materials when you join and actively participate with your associates in the field.

1.42 Certification

Certification examinations are usually administered by state regulatory agencies or professional associations. Operators take these exams in order to obtain certificates which indicate a level of professional competence. You should continually strive to achieve higher levels of certification. Successful completion of this operator training program will help you achieve your certification goals.

1.5 ACKNOWLEDGMENTS

Many of the topics and ideas discussed in this chapter were based on similar work written by Larry Trumbull and Walt Driggs.

SUGGESTED ANSWERS

Chapter 1. THE WATER DISTRIBUTION SYSTEM OPERATOR

You are not expected to have the exact answers suggested for questions requiring written answers, but you should have the correct idea. The numbering of the questions refers to the section in the chapter where you can find the information to answer the questions. Answers to questions numbered 1.0A and 1.0B can be found in Section 1.0, "Need for Water Distribution System Operators."

Answers to questions on page 4.

1.0A Water distribution operators have the responsibility of insuring that safe and pleasant drinking water is delivered to everyone's tap. Also adequate amounts of water and pressure must be available during times of emergency, such as a fire.

1.0B Water distribution system operators make sure water facilities do their intended job. Operators operate, maintain, repair and manage these facilities.

Answers to questions on page 6.

1.1A The two major sources of water supplies are (1) groundwater and (2) surface water.

1.1B Surface water is usually treated to remove suspended and dissolved materials and to kill disease-causing organisms.

Answers to questions on page 7.

1.2A Water distribution system operators should discuss proposed facilities with engineers to find out how the engineer intends for these facilities to be operated, maintained and repaired and also to make suggestions on how these jobs could be done more easily. Be sure there is adequate room for maintenance and repair equipment even during adverse weather conditions.

1.2B Adequate and reliable records are very important to document the effectiveness of your operation.

1.2C Water, distribution system operators must be able to explain the purpose and operation of their facilities to civic organizations, school classes, representatives of news media, and even to city council members or directors of their district.

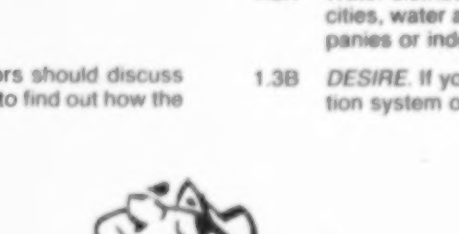
1.2D The appearance of pump stations and elevated tanks and the grounds around them indicates to the public the type of operation you maintain.

1.2E Safety is a very important operator responsibility. Most accidents result from carelessness or negligence. Safe procedures must be stressed at all times.

Answers to questions on page 8.

1.3A Water distribution system operators may be hired by cities, water agencies or districts, private utility companies or industries.

1.3B *DESIRE*. If you want to be a qualified water distribution system operator, you can do it.



WATER DISTRIBUTION SYSTEM O & M

IMPORTANT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE COMPLETING THIS FORM.

OFFICE USE ONLY
DO NOT MARK
●

Name: OPERATOR, JOE B.
Last First MI

Address: 711 MAIN STREET

SAFEWATER, CA 01234
City State Zip Code

Mail to:
Professor Kenneth Kerri
California State University, Sacramento
6000 J Street
Sacramento, California 95819

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
1	2	3	4	5	6	7	8	9	0	1
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●	1	1	1	1	1	1	1	1	1	●
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6	6	6	6	6	●	6	6	6		6
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IMPORTANT DIRECTIONS FOR MARKING ANSWERS

Use black lead pencil only (# 2 or softer).
Make heavy black marks that fill the circle completely.
Erase clearly any answer you wish to change.
Make no stray marks on this answer sheet.

1. MULTIPLE CHOICE QUESTIONS: Fill in the correct answers. If 2 and 3 are correct for question 1, mark:

   1 2 3 4 5
   1 Ⓣ ● ● ○ ○

2. TRUE-FALSE QUESTIONS: If true, fill in the circle in column 1; if false, fill in column 2. If question 3 is true, mark:

   1 2 3 4 5
   3 ● Ⓕ ○ ○ ○

Sample

Do Not Use

EXAMPLE

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4	4	4	●	4	4	4	4	4		4
5	5	5	5	●	5	5	5	5		5
6	6	6	6	6	●	6	6	6		6
7	7	7	7	7	7	●	7	7		7
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9	9	9	9	9	9	9	9	●		9

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	1	2	3	4	5
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58	Ⓣ	Ⓕ	○	○	○
59	Ⓣ	Ⓕ	○	○	○
60	Ⓣ	Ⓕ	○	○	○

DIRECTIONS FOR WORKING OBJECTIVE TEST

Chapter 1. THE WATER DISTRIBUTION SYSTEM OPERATOR

1. You have been provided with a special answer sheet (see page 11) for each chapter. Be sure you follow the special directions provided with the answer sheets. If you lose an answer sheet or have any problems, please notify the Project Director.

2. Mark your answers on the answer sheet with a dark lead pencil. Do not use ink. Be certain to mark *ALL* correct answers.

   For example, if Question 2 had three correct answers (1, 2 and 3), you should place a mark under Columns 1, 2 and 3 on the answer sheet.

   Questions 1 through 5 are true or false questions. If a question is true, then mark Column 1, and if false mark Column 2. The correct answer to Question 4 is true; therefore, place a mark in Column 1.

   Please mark your answers in your workbook for your record because answer sheets will not be returned to you.

3. Mail answer sheet to the Project Director immediately after you have completed the test.

4. Answer sheets may be folded (but not into more than 3 equal parts) and mailed in a 4 x 9½ standard white envelope.

OBJECTIVE TEST

Chapter 1. THE WATER DISTRIBUTION SYSTEM OPERATOR

Please mark the correct answers on an answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True-False

1. Water distribution system operators may receive taste and odor complaints.
   1. True
   2. False

2. Water distribution system operators may encounter hazardous conditions when doing their job.
   1. True
   2. False

3. Storage facilities for treated water at treatment plants are called "clear wells."
   1. True
   2. False

4. Most sources of surface waters are suitable for drinking purposes without any treatment.
   1. True
   2. False

5. Cross-connections are used in distribution systems to isolate portions of the system for cleaning.
   1. True
   2. False

Multiple Choice

NOTE: There may be more than one correct answer.

6. In these training manuals the water supply system has been divided into two parts, the
   1. Collection system and the treatment system.
   2. Storage system and the distribution system.
   3. Water system and the collection system.
   4. Water system and the distribution system.
   5. Well system and the treatment system.

7. Operators of water distribution systems are responsible for
   1. Health and well being of community.
   2. Insuring that safe and pleasant drinking water is delivered to everyone's tap.
   3. Keeping themselves prepared for the future.
   4. Operating and maintaining water distribution systems.
   5. Storage tanks and water mains.

8. Water distribution systems may consist of
   1. Booster pumps.
   2. Fire hydrants.
   3. Pipelines.
   4. Sewers.
   5. Valves.

9. You must operate and maintain your water distribution system to meet
   1. Drinking water regulations.
   2. Fire fighting requirements.
   3. Manpower needs.
   4. Pressure requirements.
   5. Recordkeeping requirements.

10. A water distribution system operator may be expected to
    1. Inspect the distribution system.
    2. Handle complaints.
    3. Lubricate pumps.
    4. Maintain service storage tanks.
    5. Prepare and administer budgets.

11. Where can water distribution system operators look for more information and training courses to improve themselves?
    1. American Water Works Association
    2. Colleges and universities
    3. Health departments
    4. Libraries
    5. Water utility associations

12. Typical safety hazards encountered by a water distribution system operator on the job include
    1. Careless operator not following safe procedures.
    2. Cave-ins while excavating to repair a pipe.
    3. Drowning while repairing a raw water pump.
    4. Explosive conditions when painting the inside of an elevated tank.
    5. Traffic while repairing a broken water main.

END OF OBJECTIVE TEST

CHAPTER 2

STORAGE FACILITIES

by

Dan Saenz

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Chapter 2. Storage Facilities

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OBJECTIVES

Chapter 2. Storage Facilities

Following completion of Chapter 2, you should be able to:

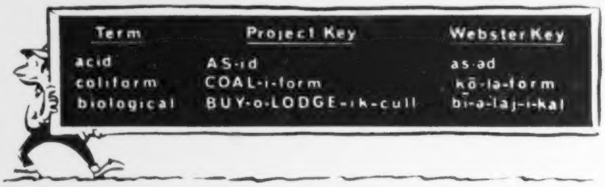
1. Identify various types of storage facilities,
2. Determine suitable locations for facilities,
3. Inspect storage facilities,
4. Take a storage facility out of service and put it back on line,
5. Safely operate and maintain a storage facility,
6. Select protective coatings for a storage facility,
7. Apply interior and exterior protective coatings to a storage facility,
8. Collect samples from a storage facility,
9. Troubleshoot storage facility problems,
10. Protect a storage facility from corrosion,
11. Disinfect a storage facility, and
12. Maintain records for a storage facility.

OPERATOR'S PROJECT PRONUNCIATION KEY

by Warren L. Prentice

The Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this Key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This Key is designed solely to aid operators in this program.

You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation Key. Each Key will be different from each other and from this Key. Examples of the differences between the Key used in this program and the *WEBSTER'S NEW WORLD DICTIONARY* "Key" are shown below:



Term	Project Key	Webster Key
acid	AS-id	as·əd
coliform	COAL-i-form	kō-lə-form
biological	BUY-o-LODGE-ik-cull	bī-ə-laj-i-kəl

In using this Key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Project Key.

	Syllable				
	1st	2nd	3rd	4th	5th
Word					
acid	AS	id			
coagulant	co	AGG	you	lent	
biological	BUY	o	LODGE	ik	cull

The first word *ACID* has its first syllable accented. The second word, *COAGULANT*, has its second syllable accented. The third word, *BIOLOGICAL*, has its first and third syllables accented.

We hope you will find the Key useful in unlocking the pronunciation of any new word.

---

[1] *The WEBSTER'S NEW WORLD DICTIONARY, Second College Edition, 1972, was chosen rather than an unabridged dictionary because of its availability to the operator. Other editions may be slightly different.*

GLOSSARY

Chapter 2. STORAGE FACILITIES

ALTITUDE VALVE ALTITUDE VALVE

A valve that automatically shuts off flow into an elevated tank when the water level in the tank reaches a predetermined level. The valve automatically opens when the pressure in the distribution system drops below the pressure in the tank.

ANODE (an-O-d) ANODE

The positive pole or electrode in an electrolytic system, such as a battery. The anode attracts negatively charged particles or ions (anions).

AVAILABLE CHLORINE AVAILABLE CHLORINE

A measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine when compared with that of elemental (liquid or gaseous) chlorine.

AVERAGE DEMAND AVERAGE DEMAND

The total demand for water during a period of time divided by the number of days in that time period. This is also called the AVERAGE DAILY DEMAND.

BACKFLOW BACKFLOW

A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes or storage tank of a potable water supply from any source or sources other than the intended source. Also see BACKSIPHONAGE.

BACKSIPHONAGE BACKSIPHONAGE

A form of backflow caused by a negative or below atmospheric pressure within a water system. Also see BACKFLOW.

CATHODE (KA-thow-d) CATHODE

The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations).

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. A low-voltage current is made to flow through a liquid (water) or a soil in contact with the metal in such a manner that the external electromotive force renders the metal structure cathodic. This concentrates corrosion on auxiliary anodic parts which are deliberately allowed to corrode instead of letting the structure corrode.

CENTRIFUGAL PUMP (sen-TRIF-uh-gull) CENTRIFUGAL PUMP

A pump consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection. As the rotating impeller whirls the water around, centrifugal force builds up enough pressure to force the water through the discharge outlet.

COLIFORM (COAL-i-form) COLIFORM

A group of bacteria found in the intestines of warm-blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm-blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.

ELECTROMOTIVE FORCE (E.M.F.) ELECTROMOTIVE FORCE (E.M.F.)

The electrical pressure available to cause a flow of current (amperage) when the electrical circuit is closed. See VOLTAGE.

FLOAT ON SYSTEM FLOAT ON SYSTEM

A method of operating a water storage facility. Daily flow into the facility is approximately equal to the average daily demand for water. When consumer demands for water are low, the storage facility will be filling. During periods of high demands, the facility will be emptying.

FOOT VALVE FOOT VALVE

A special type of check valve located at the bottom end of the suction pipe on a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

ION ION

An electrically charged atom, radical (such as SO_4^{2-}), or molecule formed by the loss or gain of one or more electrons.

PCBs PCBs

Poly**c**hlorinated **B**iphenyls. A class of organic compounds that cause adverse health effects in domestic water supplies.

PEAK DEMAND PEAK DEMAND

The maximum momentary load placed on a water treatment plant, pumping station or distribution system. This demand is usually the maximum average load in one hour or less, but may be specified as instantaneous or with some other short time period.

POSITIVE BACTERIOLOGICAL SAMPLE POSITIVE BACTERIOLOGICAL SAMPLE

A water sample in which gas is produced by coliform organisms during incubation in the multiple tube fermentation test. See Chapter 11, Lab Procedures, "Coliform Test" for details.

PRIME PRIME

The action of filling the casing with water to remove the air. Most pumps must be primed before startup or they will not pump any water.

RESIDUAL CHLORINE RESIDUAL CHLORINE

The amount of free and/or available chlorine remaining after a given contact time under specified conditions.

STALE WATER STALE WATER

Water which has not flowed recently and may have picked up tastes and odors from distribution lines or storage facilities.

TURBIDITY UNITS (TU) TURBIDITY UNITS (TU)

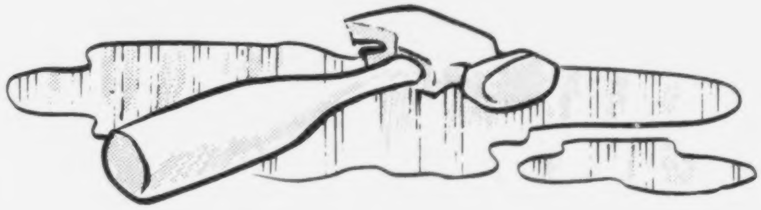
Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.

VOLTAGE VOLTAGE

The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. See ELECTROMOTIVE FORCE (E.M.F.).

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.



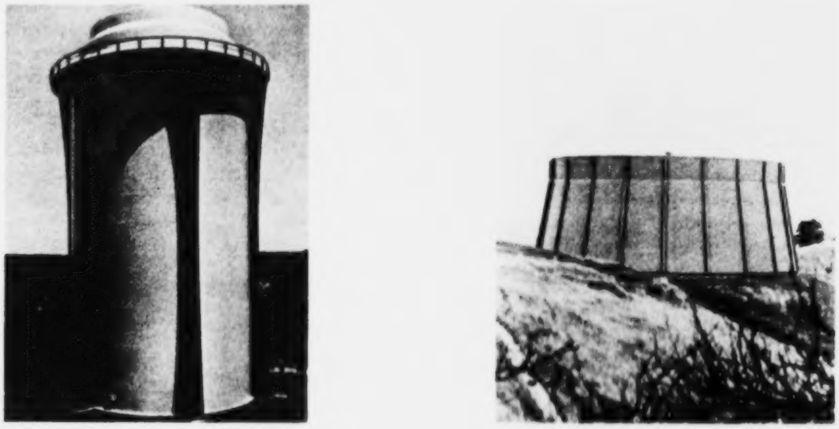
CHAPTER 2. STORAGE FACILITIES

2.0 PURPOSE OF STORAGE FACILITIES

The main purpose of a water storage facility is to provide a sufficient amount of water to average or equalize the daily demands on the water supply system. The storage facility should be able to provide water for *AVERAGE*[2] and *PEAK DEMANDS.*[3] Also, the storage facility helps maintain adequate pressures throughout the entire system.

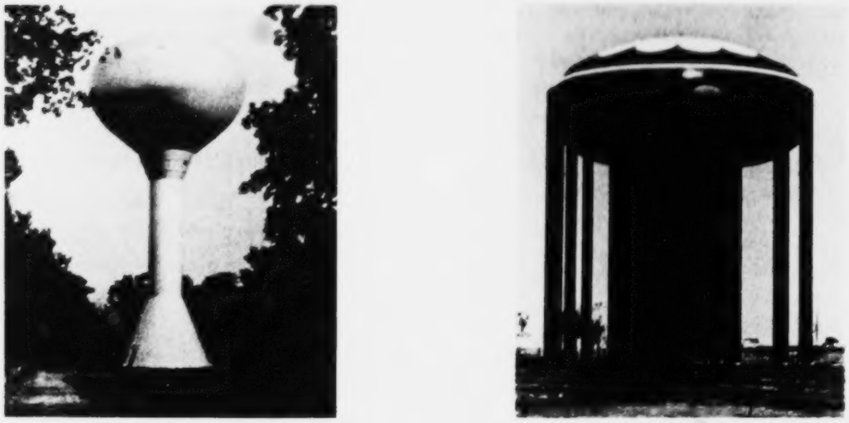
Other purposes of water storage include meeting the needs for fire protection, industrial requirements, and reserve storage. During a fire or other type of emergency, sufficient storage should be available to meet fire demands, as well as other demands, and also maintain system pressures. In some areas the water supply system may serve some type of industry. Storage requirements will depend on the type of industry and the flow and pressure demands of the industrial activities of each industrial facility served by the water supply system. Reserve storage requirements depend on standby requirements and alternate sources of water supply. Reserve requirements may be specified by fire insurance regulations. Reserve storage capacity may be provided to meet future growth and development demands of the area being served.

Reservoirs are storage facilities and may be of several different types. We often think of a reservoir as an open body of water contained by an earth-fill dam or a concrete dam. This chapter, however, will discuss various types of steel and concrete-type tanks which are basically covered distribution system reservoirs for the storage of treated water and are commonly used in most water systems, especially small water systems (Figures 2.1 and 2.2).



2,000,000-Gallon standpipe — Brown Deer, Wis.

1,700,000-Gallon Reservoir — Pleasant Hill, Calif.



Warwick, R.I.; 500,000-Gallon Pedestal Spheroid.

Denton, Texas; 2,000,000-Gallon Turbospherical.

Fig. 2.1 Photos of typical storage facilities

(Permission of Pittsburgh-Des Moines Corporation)

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[1] *For additional information on storage facilities, see Chapter 3, "Reservoir Management and Intake Structures," in WATER TREATMENT PLANT OPERATION, Volume I, of this series of manuals.*

[2] *Average Demand. The total demand for water during a period of time divided by the number of days in that time period. This is also called the AVERAGE DAILY DEMAND.*

[3] *Peak Demand. The maximum momentary load placed on a water treatment plant, pumping station or distribution system. This demand is usually the maximum average load in one hour or less, but may be specified as instantaneous or with some other short time period.*

The requirements for a specific storage facility will depend upon a system's individual needs. To select a suitable type of storage facility, the answers to the following questions must be known:

1. What is the maximum-day use?
2. What is the maximum-hourly use?
3. What type of pressure will the facility be required to provide and maintain throughout the system?
4. What size will be necessary to fulfill the requirements for emergencies such as fire flow?

Water storage facilities are used to store water from wells or water treatment facilities at times when demands for water are low and to distribute the water during periods of high demand. Water storage facilities are found at one or more locations in areas closest to the ultimate users, where higher pressures are needed, and where land is available. The advantages of distribution system storage are:

1. Demands on the source of water, the pumping facilities, and the transmission and distribution mains are more nearly equalized and also the capacities of the tanks and other treatment facilities in the system need not be so large.
2. System flows and pressures are improved and stabilized, thus providing better service to the customers in the area.
3. Reserve water supplies are provided in the distribution system for emergencies such as fire fighting and power outages.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.0A What are the purposes of water storage facilities?

2.0B List the advantages of distribution system storage.

2.1 TYPES OF STORAGE FACILITIES

The following types of storage facilities are common to a water system: clear wells (Figure 2.3), elevated tanks (Figure 2.4), stand pipes (Figure 2.5), ground-level storage tanks (Figure 2.6), hydropneumatic or pressure tanks (Figure 2.7) and surge tanks (Figure 2.8). Let's study the definition of each tank and the differences among the tanks.

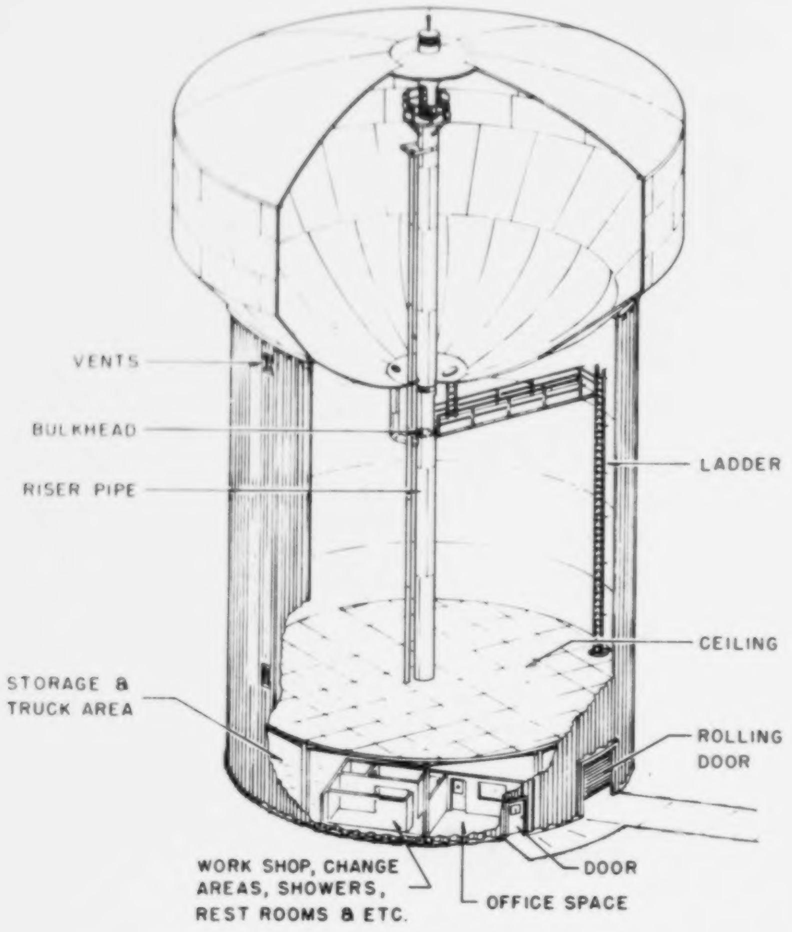

Fig. 2.2 Elevated tank (cross-sectional view)

(Permission of Pittsburgh-Des Moines Corporation)

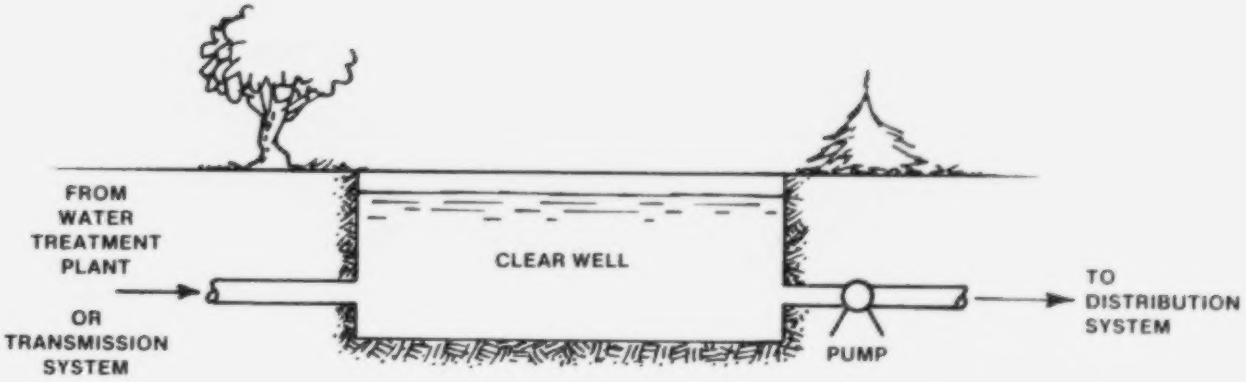
FROM
WATER
TREATMENT
PLANT
OR
TRANSMISSION
SYSTEM
CLEAR WELL
PUMP
TO
DISTRIBUTION
SYSTEM

Fig. 2.3 Clear well

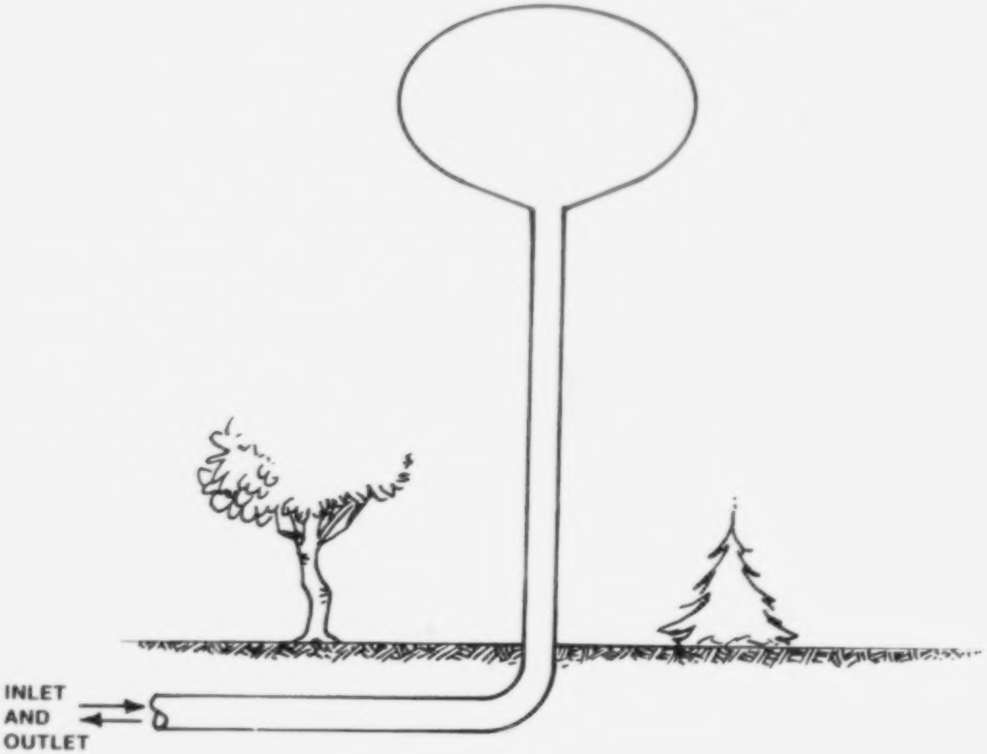
INLET
AND
OUTLET

Fig. 2.4 Elevated storage tank

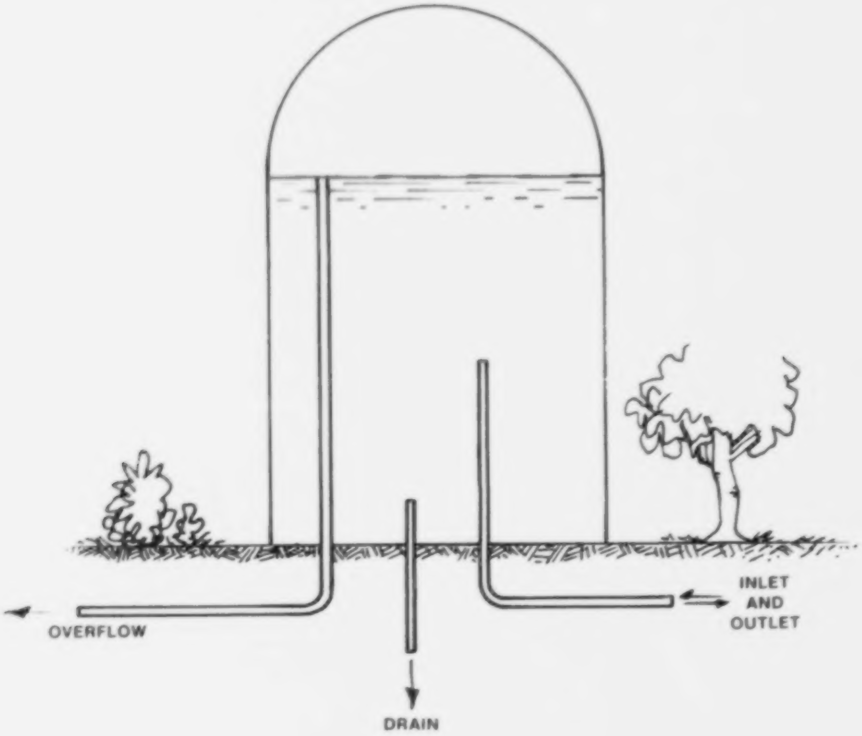
OVERFLOW
DRAIN
INLET AND OUTLET

Fig. 2.5 Stand pipe

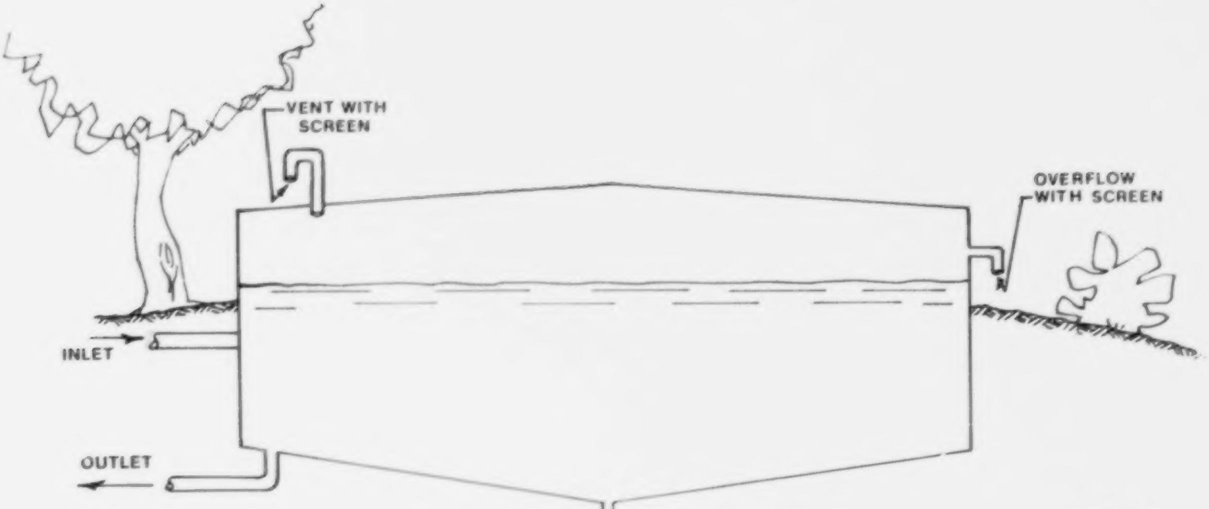
VENT WITH SCREEN
OVERFLOW WITH SCREEN
INLET
OUTLET
GRAVITY DRAIN TO DAY LIGHT

Fig. 2.6 Ground-level service storage reservoir

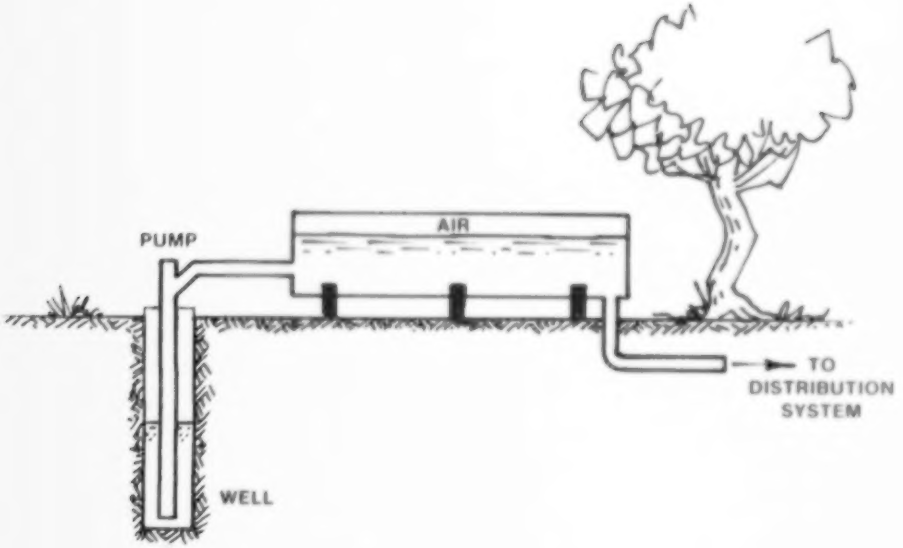
AIR
PUMP
WELL
TO DISTRIBUTION SYSTEM

Fig. 2.7 Hydropneumatic or pressure tank

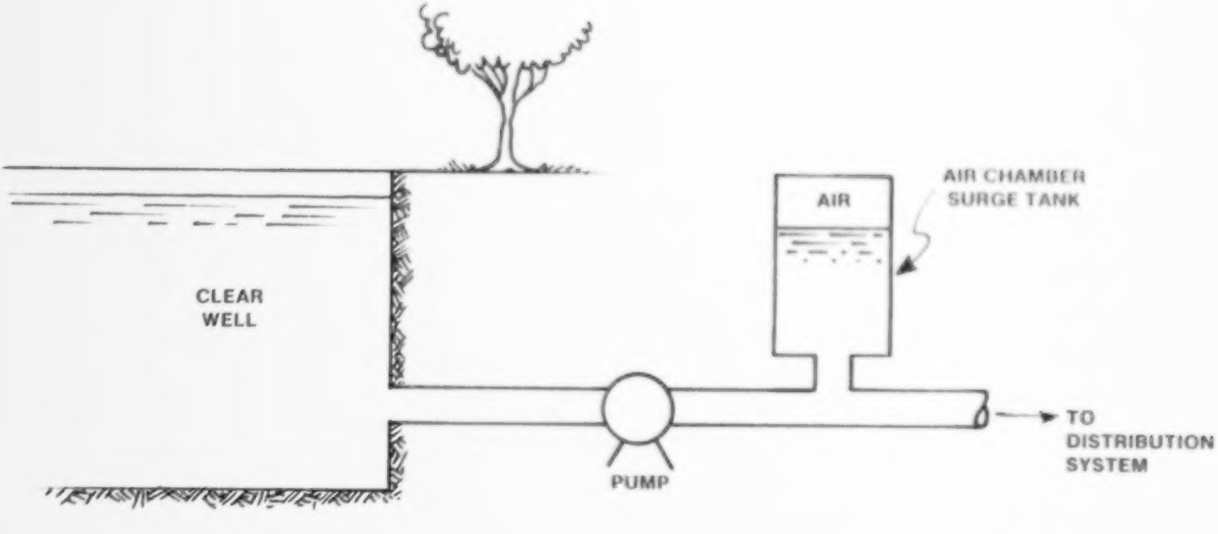
CLEAR WELL
AIR
AIR CHAMBER SURGE TANK
PUMP
TO DISTRIBUTION SYSTEM

Fig. 2.8 Surge tank

2.10 Clear Wells

Clear wells are used for the storage of filtered water from a treatment plant. These storage tanks are of sufficient capacity to allow fairly constant filtration rates. This type of storage facility will allow a filter plant to operate continuously at an average flow rate and place neither fluctuating nor excessive demands on the filters. Clear wells store excess water when the demand for water is low and supply additional water when the demand is high.

Clear wells may be located below the ground surface and are often made of concrete. They must be protected from contamination and unauthorized entry. Periodically they must be inspected for leaks.

2.11 Elevated Tanks

Elevated tanks are elevated above the service zone and are used primarily to maintain an adequate and fairly uniform pressure to that service zone. They are often installed where the land is flat. Elevated tanks are used to:

1. Eliminate the need for continuous pumping,
2. Minimize variations in distribution system water pressures due to short-term shutdowns of power or pumps,
3. Equalize the water pressure in the distribution system by the proper location of the tanks,
4. Provide a small amount of water for storage (especially to meet demands such as fires), and
5. Reduce auxiliary power requirements.

One limitation of elevated tanks is that the pressure in the distribution system may vary with the water level in the tank.

2.12 Stand Pipes

Stand pipes are tanks that stand on the ground and have a height greater than their diameter. For example, a tank that has the following dimensions is a stand pipe — a 10-foot (3 m) diameter and a height of 20 feet (6 m). The bottom of a stand pipe is on the ground, whereas the bottom of an elevated tank is above the ground.

Stand pipes may be constructed of steel or concrete. They are usually located on high ground at or near a well field or at a point in the distribution system where equalizing storage is needed. Stand pipes are used to lower fire insurance costs of consumers. When compared with elevated storage tanks, stand pipes are preferred because they are:

1. Easier to maintain,
2. More accessible for observation and sampling to determine quality of stored water,
3. Safer to work around, and
4. Less objectionable from an aesthetic viewpoint.

Stand pipes constructed of steel require more maintenance than those built of concrete.

Stand pipes can provide large volumes of water at low pressures. This storage is available for fire protection if fire pumpers are used. When operating under these conditions, you may create a vacuum on the distribution system. This may result in the introduction of contamination to the mains. If this happens, you must issue boil orders to your consumers, flush the system and sample for *COLIFORMS*[4] to be sure the water is safe to drink.

2.13 Ground-Level Reservoirs

Most ground-level reservoirs are constructed of concrete and are either circular or rectangular in shape. They may be buried in the ground or located on the ground surface. All reservoirs should be covered to reduce the possibility of contamination. Some concrete reservoirs are built with parks, parking lots, or tennis courts on top of them. These reservoirs are located above the service area to maintain the required pressures.

All storage facilities should be located above drainage areas and locations subject to flooding. Care must be taken to insure that runoff water and debris cannot enter the reservoir and contaminate the water. Overflow and air vents should be screened so that birds, rodents and debris cannot enter the reservoir. Vents must be adequate and never be blocked so air can flow freely without any obstruction. Properly functioning vents are essential to prevent a pressure developing in the reservoir when it fills or a vacuum when it empties or is drained. Reservoirs must be fenced to prevent access by vandals or other unauthorized persons.

2.14 Hydropneumatic or Pressure Tanks

A hydropneumatic tank contains a system in which a water pump is controlled by the air pressure in a tank partially filled with water. This type of facility is usually found in smaller water systems. Hydropneumatic tanks are used with a well or a booster pump in water supply systems that do not have a storage reservoir. The tank is used to maintain water pressures in the system and to control the operation of the pump. *CAUTION:* Hydropneumatic tanks are pressure vessels. Care must be used because of the high pressure in the tank when operating and maintaining these facilities, especially the pressure relief valves.

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[4] *Coliform (COAL-i-form). A group of bacteria found in the intestines of warm-blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm-blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.*

Hydropneumatic tanks must contain the proper amount of air to be effective. The recommended water to air ratio is approximately two-thirds water to one-third air. If there is not enough air in a hydropneumatic tank, the pump may operate continuously. An automatically operated air pump should be available to maintain the proper amount of air. The tank should have a sight glass so the water-air ratio in the tank can be observed.

Limitations of hydropneumatic or pressure tanks include the fact that they do not provide much storage to meet demands during power outages. Also a very limited amount of time is available to do maintenance or repair work on wells, pumps or water treatment equipment. If a pressure filter must be washed using water from a pressure tank, the amount of water remaining in storage and pressure in the system may become fairly low by the time the backwash job is completed. For additional information on hydropneumatic and pressure tanks, see Chapter 3, Wells, Sections 3.29, "Hydropneunamtic Pressure Tank System," and 3.15, "Determination of Working Pressure," in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

2.15 Surge Tanks

Surge tanks are not necessarily storage facilities, but are used mainly to control *WATER HAMMER*[5] or to regulate the flow of water. Their primary purpose is to protect pipelines against destruction due to excess surge pressure (water hammer). Surge tanks are filled with air and allow the pressure surge to flow into the air space instead of stressing the pipeline. Surge tanks do not absorb energy. Their function is simply to absorb the sudden surge (pressure of water) in the air space thus eliminating possible breaks in the distribution system pipelines. An insufficient amount of air in a surge tank will defeat its intended purpose and will allow surge problems in the distribution system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.1A List the five common types of tanks found in water supply systems.

2.1B What is a clear well and its purpose?

2.1C What is the main purpose of an elevated storage tank?

2.2 SELECTION AND LOCATION OF STORAGE FACILITIES

The selection of the type of storage facility or tank depends on the system's individual needs and the type of terrain (land surface) where it is to be installed. Normally a clear well is located immediately downstream from a water treatment plant. The capacity of the clear well should be sufficient to allow a water filtration plant to operate at a constant rate during periods of peak demands.

An elevated tank is used primarily to supply adequate pressure to a service area. A pump is used to lift water to the elevated tank which provides the head (ft) or pressure (psi) to the service zone. When the water level falls in the tank, a low level or pressure switch will activate an electrical circuit which will start a pump. This pump will begin the fill cycle before the tank runs completely dry.

A stand pipe may be a ground-level storage facility located at the highest point in a system or it may provide ground storage at a booster station.

A hydropneumatic tank is commonly used with small well systems. The well provides a source of water which is pumped to the tank. Air in the tank helps maintain pressure in the distribution system.

A surge tank is not a storage facility in the truest sense. Surge tanks are necessary to control the problem of surges and water hammer. The surge tank should always be located as close as possible to the activity which creates the water hammer. See the Appendix at the end of this chapter for a discussion on "Surge in Pipelines Carrying Liquids."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.2A The selection of the type of storage facility or tank depends on what two factors?

2.2B Elevated storage tanks are commonly used for what purpose?

2.3 OPERATION[6]

2.30 Storage Tanks

Procedures for operating storage tanks will vary depending on the design of the facilities and the demands for water. Typical procedures could include (1) filling all storage tanks during periods of off-peak electrical demands and/or (2) maintaining specified minimum pressures at certain critical points in the distribution system.

Normally, storage tanks are installed to supply water during periods of high water demand. Therefore, during periods of low water demand, the excess pumping capacity is used to fill the tanks before the next period of high water demand occurs. If off-peak electrical energy is available at reduced rates, the pumps can be operated during this period to fill the storage tanks.

All storage tanks should be operated according to the design engineer's and manufacturer's instructions. We must remember that in the design stages of any water system, there usually is a valid reason for the type of storage tank that was selected. Small changes in the distribution system usually will not change the requirements of the storage facility. For example, pipeline extensions or the addition of a few new services. Major system changes, such as larger size main lines or the installation of multiple services, can change storage requirements and may require more tank storage.

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[5] *Water Hammer. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.*

[6] *For additional information on operation, see Chapter 5, "Distribution System Operation and Maintenance."*

Frequently the water supplier tries to maintain specified minimum target water pressures throughout the distribution system. Under these circumstances, the pump or pumps are operated whenever needed to maintain the desired pressures. Sometimes there may be several pumps available and they may be variable-speed pumps. The operator maintains pressures throughout the system by regulating the number of pumps operating and/or controlling the pump speed.

Many water supply systems are instrumented and automated. Instruments are used to measure water pressures automatically throughout the distribution system and to measure water levels in service storage tanks. Whenever water pressures or water levels drop below minimum target levels, pumps will automatically be started. These pumps will stay on until pressures or water levels reach maximum levels and then the pumps will stop. In some systems there may be more than one minimum level. For example, pump number one may come on at one pressure or water level and pump number two may start at a lower level.

Operators of automated systems must inspect the measuring instruments (pressure gages and water levels) for proper measurement and must also be sure the pumps start and stop at the proper levels. Sections 2.50, "Booster Pumps," and 2.52, "Gages," discuss the maintenance and troubleshooting of pumps and gages.

A modification of normal operating procedures which can reduce costs is the "time-of-day" pumping concept. With this method pumps are used only during the off-peak hours of electrical usage — namely during the hours between 10 p.m. and 6 a.m. Many electrical utilities offer a special lower rate for usage of electricity during off-peak hours.

Abnormal operating conditions include (1) excessive water demands, such as fire demands, (2) broken or out-of-service pumps, mains or tanks, and (3) *STALE WATER*[7] in tanks creating tastes and odors in systems before design demand flows develop. Emergency plans must be developed in cooperation with the fire department which specify how operators should respond when a fire occurs. A serious fire will require that all pumps operate at full capacity. When all pumps are operating at full capacity, there is a significant danger of *BACKSIPHONAGE*[8] into the water supply. Whenever large pumps are put on line or taken off line, care must be exercised so that surges (water hammer) do not burst pipes due to excessive pressure or collapse pipes due to negative pressures caused by pressure surge waves. These pumping conditions can also create electrical power surges which may cause pump motors to trip out (stop working) and produce even more serious problems.

Failures of pumps, mains and tanks create serious problems. Emergency response plans must be developed *IN ANTICIPATION* of these events. Such planning could reveal the need for backup or alternative systems. Many water utility agencies have standby pumps and generators for use during emergencies. Know where you can obtain additional pumps, pipes, fittings and other necessary supplies and equipment during emergencies. The purchase and storage of essential items *IN ADVANCE* may be appropriate. Temporary (and then permanent) repairs should be made as quickly as possible to avoid overloading the remaining facilities and to prevent additional breakdowns.

ADDITIONAL PUMPS, PIPES, FITTINGS AND OTHER NECESSARY SUPPLIES

An emergency public relations program may be helpful to encourage consumers to reduce water usage during periods when facilities are overloaded. If the public understands the nature and seriousness of a crisis, they will usually cooperate.

New facilities are sometimes constructed and placed on line before a significant demand for water has developed. Under these circumstances, large quantities of water may remain in storage facilities for excessive time periods allowing tastes and odors to develop in the water. To avoid this problem, periodically allow a storage tank to empty and then refill. The tank could be emptied into the system and used by consumers. If this is not possible, the tank could be drained and the water wasted.

---

[7] **Stale Water.** *Water which has not flowed recently and may have picked up tastes and odors from distribution lines or storage facilities.*

[8] **Backsiphonage.** *A form of backflow caused by a negative or below atmospheric pressure with a water system. Also see BACKFLOW.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.3A Tank storage capacity can become inadequate due to what two factors?

2.3B What is the "time-of-day" pumping concept?

2.3C How are instruments used to operate water supply systems?

2.3D List three abnormal conditions encountered by operators of water storage facilities.

2.31 Storage Levels

The main function of a distribution storage facility is to take care of daily demands and especially peak demands. Operators must be concerned with the amount of water in the storage facility at particular times of the day. Water levels drop during peak demands and gain during low demands. Most distribution systems establish a pattern which the operator should study in order to better anticipate system demands. Figure 2.9 shows a typical water usage flow curve over a 24-hour period. Ideally, extra water is supplied from storage during the hours that consumption is above average and water is delivered to fill up the storage facility during the hours consumption is below average flows. The pattern for any particular system not only varies during the day as shown in Figure 2.9, but varies during different days of the week, especially on weekends and holidays. Demands for water also change during different times of the year because of varying weather conditions. Knowing these patterns, the operator can better anticipate and be ready for expected high demand periods. The operator should know how high the water level should be each morning so that the system's demands will be met during the rest of the day.

The volume of water in a reservoir can be readily determined if you know the water level. Water level indicators are, therefore, essential to successful reservoir operation. Devices range from a simple float connected to an indicator that goes up and down on a staff gage and which can be directly read (Figure 2-10), to telemetry equipment that transmits information concerning water levels to any distance and does it continuously or on demand. Recorders might also be used. Staff gages normally have water level readings in feet and the level noted can be readily converted to the volume of water stored in the reservoir (see *EXAMPLE 1*). Each reservoir should be read at approximately the same time each day and the readings recorded. Checks should be made at other times of the day to determine whether any unusual demand conditions have occurred. If any significant increase in demand over that anticipated is noted, the operator should initiate an earlier increase of flow to the reservoir. Automatic water level regulation can be achieved using *ALTITUDE-CONTROL VALVES.*[9] These valves are designed to (1) prevent overflows from the storage tank or reservoir, or to (2) maintain a constant water level as long as water pressure in the distribution system is adequate. The simplest form of level control is a pressure activated switch which turns a pump on and off. This switch is often sufficient for small water systems. The use of advance warning alarms to signal when water levels are too low or too high is recommended.

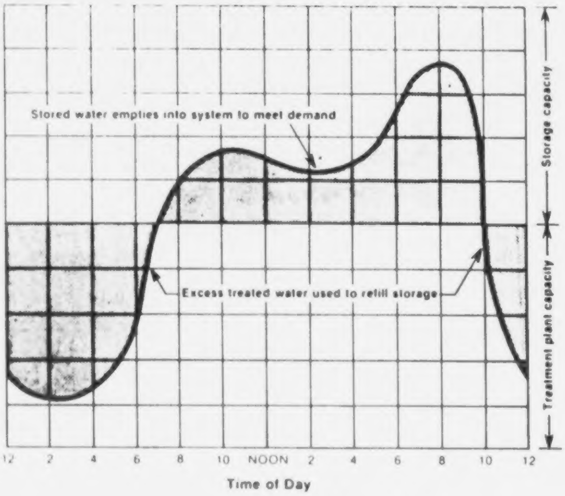

Fig. 2.9 Typical daily use (summer) flow curve

(Reprinted from OPFLOW, July 1978 issue, by permission. Copyright 1978, the American Water Works Association)

A number of routine checks need to be made at reservoirs depending on the type of equipment available. If advance warning alarms are used, they should be tested to insure they will work when needed. In many reservoirs the water level is controlled automatically. Provisions should be made to allow the operator to test the system to be sure it is working properly. Time clocks are often used to operate valves or pumps which control water coming into the reservoir. They should occasionally be checked and reset if necessary. If they malfunction, the water level could vary too widely. Problems can also be caused by sticking or nonseating valves. The operator must be certain that all altitude and overflow valves in use are in good working condition.

FORMULAS

To determine the volume of a storage facility, we need to know the dimensions of the facility. If the tank is rectangular, we need to know the length, width and depth of water.

Volume, cu ft = (Length, ft)(Width, ft)(Depth, ft)

If the tank is circular, we need to know the diameter and depth of water.

Volume, cu ft = (0.785)(Diameter, ft)^2(Depth, ft)

To convert a volume from cubic feet to gallons, we multiply the volume in cubic feet by 7.48 gallons per cubic foot.

Volume, gal = (Volume, cu ft)(7.48 gal/cu ft)

EXAMPLE 1

Estimate the volume of water (cubic feet and gallons) in the tank shown on Figure 2.10. The tank is 20 feet in diameter and 35 feet deep. The target indicates that the depth of water is 22 feet and the water level indicates that the water is 13 feet from the top of the tank.

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[9] ***Altitude Valve.*** *A valve that automatically shuts off flow into an elevated tank when the water level in the tank reaches a predetermined level. The valve automatically opens when the pressure in the distribution system drops below the pressure in the tank.*

Known		Unknown
Diameter, ft	= 20 ft	1. Volume, cubic feet
Depth, ft	= 22 ft	2. Volume, gallons

1. Calculate the volume of water in the tank in cubic feet.

$$\text{Volume, cu ft} = (0.785)(\text{Diameter})^2(\text{Depth, ft})$$
$$= (0.785)(20\text{ ft})^2(22\text{ ft})$$
$$= 6908\text{ cu ft}$$

2. Calculate the volume of water in the tank in gallons.

$$\text{Volume, gal} = (\text{Volume, cu ft})(7.48\text{ gal/cu ft})$$
$$= (6908\text{ cu ft})(7.48\text{ gal/cu ft})$$
$$= 51{,}672\text{ gallons}$$

Many operators prepare tables or charts that contain the volume in a tank for each foot in depth. These tables and charts could be prepared for the tank in *EXAMPLE 1* by reworking the problem for depths other than 22 feet. With these tables and charts, the operator records the depth in the tank, refers to the table or chart, and obtains the volume of water in the tank.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.3E What is the main function of a distribution storage reservoir?

2.3F Why should operators know how high the level in a storage tank should be each morning?

2.3G How are water levels controlled in storage reservoirs?

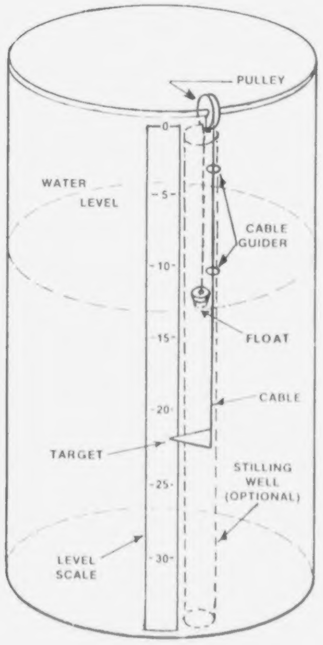


Fig. 2.10 Measuring water level in a tank

2.32 Storage Level Controls

There are several different types of control systems used to monitor water levels in storage facilities and also to start and stop pumps. One of the simplest types of control systems uses electrodes mounted at various levels in the storage facility. These electrodes sense the rise and fall of the water level and start and stop the pumps as necessary.

Two problems may be encountered by operators of this type of control system. When the electrodes need replacement or repair, they can be difficult to reach. This problem can be solved by placing the electrodes at a location where access is easy. Another problem with probes is that they may corrode or become contaminated, thus requiring replacement.

Another method of sensing water levels in a storage facility is the use of ultrasonic signals. A transmitter sends a continuous high-frequency sound wave to a receiver. When the receiver is covered with water, the signal is broken. Once the signal is broken, a pump can be started or stopped depending on the desired situation in the storage tank.

Pressure switches are also placed in storage facilities to start or stop water pumps. These switches can be set to respond to changes in water pressure. One difficulty associated with pressure switches is that they require an extremely critical calibration procedure to get the switches to respond at the proper water surface level. If a switch must be replaced, the calibration procedure must be repeated.

Solid-state electronic sensors are available that can measure the actual water surface level and start or stop a pump. Calibration of solid-state electronic sensors consists of dialing the set point to the desired start or stop water surface level for a pump.

Differential-pressure altitude valves are also used to regulate water surface levels in a storage facility. These valves shut off flow into a storage facility when it becomes full and reopen when the tank level drops to a predetermined level or the pressure in the distribution system drops to a predetermined level.

Pump stations are not always located in the same place as the storage facility. Under these conditions a signal must be transmitted from the storage facility to the pump or pumps. Also some type of indicator showing the level of water in the storage facility is desirable at the pump station.

The transmission cable may be underground or an overhead wire may be used to transmit signals from a tank to a pump. Underground cable should be of the armored variety to protect it from rodents. Radio frequencies are also used to transmit signals from sensors to pumps. Problems may develop if lightning or excessive voltage interferes or disrupts the signals. These improper signals may cause a pump to start or stop at the wrong time. Lightning protectors can be installed to prevent the disruption of signals.

Usually when a pump receives a signal to start, a light will come on in the control panel indicating that the pump is running. In order to be sure that the pump is actually pumping water, a positive flow report-back signal should be installed on the control panel. This report-back signal may be a flow meter, an ultrasonic flow switch, a pressure switch, or a check-valve, arm-actuated mercury switch.

Most water utilities need only a small amount of instrumentation and controls. The best approach is to purchase high quality instruments that will require little maintenance and operate for many years. If at all possible, the simple maintenance should be performed by the utility's operators.[10]

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.3H How can the depths of water in a storage facility be measured?

2.3I What problems are created by the use of electrodes to measure water depths?

2.3J What problem could occur when the pump running light is on?

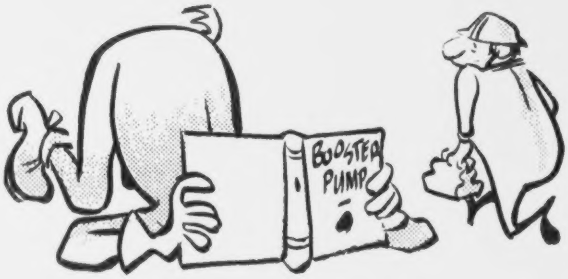
2.33 Pumps

CENTRIFUGAL PUMPS[11] (Figure 2.11) cannot operate unless the impeller is submerged in water, *NEVER ATTEMPT TO START A CENTRIFUGAL PUMP UNTIL YOU KNOW THAT THE PUMP IS PROPERLY PRIMED*[12] (Figure 2.12). There are several ways to prime a pump so the impeller is submerged in water. A special primer pump may be used to pump water into the pump casing and submerge the impeller. A priming water tank or an auxiliary water supply may be used to prime the pump by adding water to the pump casing and bleeding off the air in the casing. Air may be removed from the pump casing by the use of an electric or hand-operated vacuum pump which causes water to flow into the suction pipe and pump casing. *FOOT VALVES*[13] (Figure 2.12) may be installed on the inlet of the pump suction pipe to keep the pump and suction line full of water. However, if the foot valve develops a leak, the pump will lose its prime. If the pump impeller is located below the surface of the water being pumped (such as a booster pump), the pump will not need to be primed.

When starting an electric motor-driven centrifugal pump, the following procedure is recommended:

1. Check the lubrication,
2. Prime the pump and make sure that the pump and suction piping are free of air,
3. Reduce electric current and water surge on startup by starting the pump with the discharge valve closed or throttled,
4. Open the discharge valve slowly as soon as the pump is running,
5. Inspect the packing glands to see that water seals are functioning properly, and
6. Measure the running amperage and investigate any abnormal demands or changes from the usual readings.

Continuously operating pumps should be inspected on a regular basis. Inspection should include observing and recording pump suction and discharge pressures, output flow, and electrical current demands. Also check for excessive or abnormal noises, vibrations, heat and odors. If the packing glands are leaking excessively, they should be tightened so that there is only a small amount of leakage. This small amount of leakage helps cool the pump shaft and reduce premature packing wear and scored shaft sleeves. Do not tighten too much and cause an increase in heating and/or damage to the pump. If a centrifugal pump does not operate as expected, refer to Section 2.50, "Booster pumps," Table 2.2, Centrifugal Pump Troubleshooting Chart.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.3K When is a pump primed?

2.3L How can a pump be primed?

2.3M How can the electric current and water surge be reduced when starting a centrifugal pump?

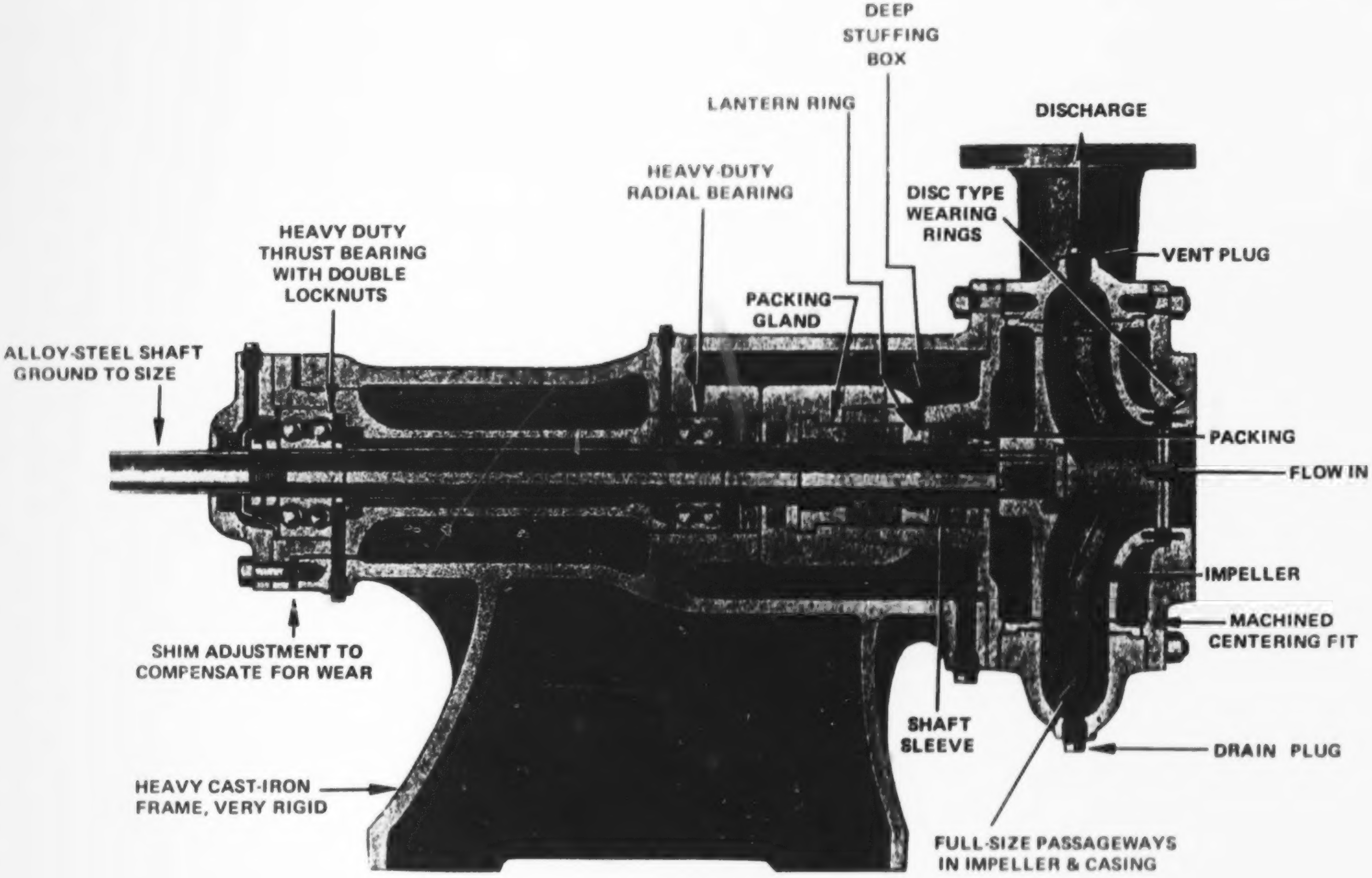
---

[10] *For additional information on instrumentation and controls, see Chapter 19, "Instrumentation," in WATER TREATMENT PLANT OPERATION, Volume II, in this series of manuals.*

[11] *Centrifugal Pump (sen-TRIF-uh-gull). A pump consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an outlet and discharge connection. As the rotating impeller whirls the water around, centrifugal force builds up enough pressure to force the water through the discharge outlet.*

[12] *Prime. The action of filling the casing with water to remove the air. Most pumps must be primed before startup or they will not pump any water.*

[13] *Foot Valve. A special type of check valve located at the bottom end of the suction pipe of a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out the suction pipe.*


DEEP STUFFING BOX
LANTERN RING
DISCHARGE
HEAVY-DUTY RADIAL BEARING
DISC TYPE WEARING RINGS
VENT PLUG
HEAVY DUTY THRUST BEARING WITH DOUBLE LOCKNUTS
PACKING GLAND
ALLOY-STEEL SHAFT GROUND TO SIZE
PACKING
FLOW IN
IMPELLER
MACHINED CENTERING FIT
SHIM ADJUSTMENT TO COMPENSATE FOR WEAR
SHAFT SLEEVE
DRAIN PLUG
HEAVY CAST-IRON FRAME, VERY RIGID
FULL-SIZE PASSAGEWAYS IN IMPELLER & CASING

00. 44

00 45

Fig. 2.11 Source water centrifugal pump

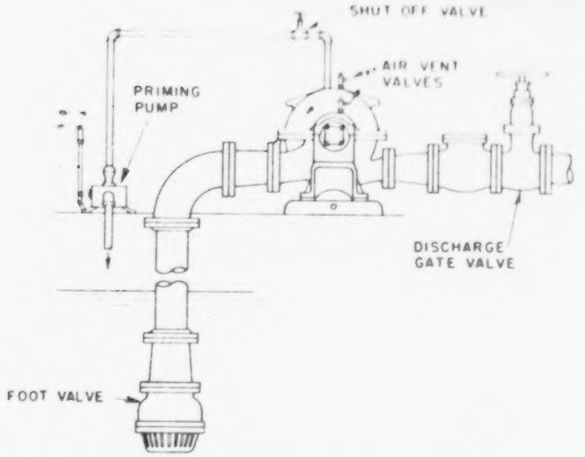


Fig. 2.12 Pump priming installation

(Reprinted from WATER DISTRIBUTION OPERATOR HANDBOOK, by permission. Copyright 1976, the American Water Works Association)

2.34 Sampling

All storage facilities should be regularly sampled to determine the quality of water which enters and leaves the facility. Sampling data and visual observations can help you establish a routine for the periodic cleaning of the tank. Indicators which may help you decide when the tank will need cleaning are turbidities over an accepted standard (such as 1.0 *TURBIDITY UNITS*[14]); excessive color, tastes and, of course, *POSITIVE BACTERIOLOGICAL SAMPLES*[15] which indicate the presence of bacterial contamination.

2.35 Troubleshooting

If water quality problems develop, you must determine where the problem is coming from and what action will be taken to solve the problem. Table 2.1 is a summary of water quality problems which may develop in storage tanks and distribution systems. The table lists the problems, identifies possible causes, and proposes potential solutions. You will learn more about how to solve water quality problems as you continue through this manual. For additional information, see Chapter 4, Water Quality Problems in Distribution Systems, Section 4.52, "Quality Degradation in Storage Facilities."

In some areas where seasonal demands become very low, the chlorine residual may become depleted in the storage tank due to excessive detention time. If this is a problem, auxiliary chlorination stations may be needed in the distribution system or at secondary or booster pump stations to maintain desired chlorine residuals.

In addition to troubleshooting water quality problems, you should regularly inspect the storage facility. Be sure the gate to the facility is locked to keep out vandals and unauthorized persons. The access opening to the facility must be locked and provide a seal to keep out rain and debris. All vent, overflow, and drain screens must be in good condition. Carefully inspect the tank cover for any defects. Look at the water surface for debris and dead birds and rodents.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.3N Which water quality indicators may help you decide when a storage tank needs cleaning?

5.3O List three possible causes of tastes and odors in a drinking water supply.

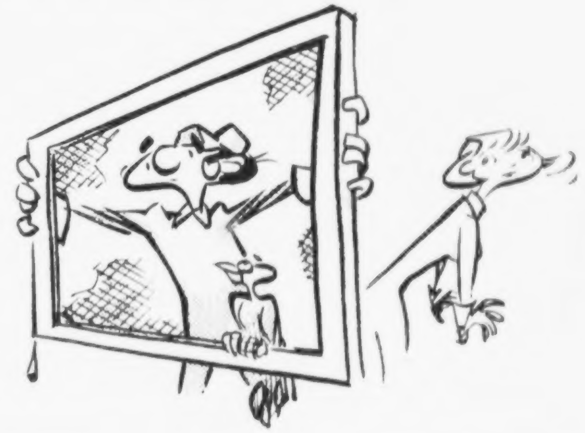
2.3P List three possible causes of positive coliform test results in a water storage tank.

2.4 MAINTENANCE[16]

2.40 Preventive and Corrective Maintenance

Maintenance is the necessary key in the efficient operation of any water system. Webster says that "maintenance is the upkeep of property or equipment." There are two types of maintenance — preventive and corrective. Preventive maintenance is something which is done before some type of deterioration takes place. Painting puts a protective covering on the tank thus protecting it from deterioration (rust formation).

Corrective maintenance or repair is maintenance which is necessary when a problem already exists. An example is the replacing of deteriorated overflow and vent screens on a tank which have failed and do not serve the purpose of keeping birds or rodents out of the tank.



Problems will not disappear — they only get worse. For that reason alone, maintenance is important.

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[14] *Turbidity Units (TU). Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.*

[15] *Positive Bacteriological Sample. A Water sample in which gas is produced by coliform organisms during incubation in the multiple tube fermentation test. See Chapter 7, Lab Procedures, "Coliform Test," for details in SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

[16] *For additional information on maintenance, especially equipment maintenance, see Chapter 18, "Maintenance," in WATER TREATMENT PLANT OPERATION, Volume II, in this series of manuals.*

TABLE 2.1 TROUBLESHOOTING WATER QUALITY PROBLEMS IN STORAGE TANKS AND DISTRIBUTION SYSTEMS

Problem	Possible Cause	Potential Solution
1. Tastes and Odors	High chlorine residual	Use *BREAKPOINT CHLORINATION*[a] or lower chlorine dosage
	Biological (algal) growth or microorganisms	Chlorinate
	Dead end in main or tank	Flushing or eliminate dead end
2. Turbidity	Silt or clay in suspension	Flushing of mains or proper operation of water treatment plant (proper coagulant, dosage, and operation of coagulation, flocculation and filtration processes)
	Calcium carbonate	
	Aluminum hydrate, precipitated iron oxide	
	Microscopic organisms	
	Floc carryover	
3. Color	Decay of vegetable matter	Chlorination
	Microscopic organisms	Chlorination
4. Positive Coliform Results	Contaminated distribution system	Locate and remove source
	Cross-connection	Install backflow prevention or *AIR GAP*[b] devices, flush and temporarily increase chlorine dosage
	Negative pressure in main	Repair main, increase chlorine feed rate, flush system and *SAMPLE.* Maintain a positive pressure in main (at least 5 psi, 0.35 kg/sq cm or 34.5 kPa)
	No or improper disinfection of new or repaired wells, reservoirs or mains	Use proper disinfection procedures

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[a] Breakpoint Chlorination. Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

[b] Air Gap. An open vertical drop, or vertical empty space, that separates a drinking (potable) water supply to be protected from another water system in a water treatment plant or other location. This open gap prevents the contamination of drinking water by backsiphonage or backflow because there is no way raw water or any other water can reach the drinking water.

2.41 Painting

Several factors must be considered before painting the outside of a storage tank. Many water utility agencies try to paint the outside of their steel tanks once every five years. The time a coating lasts depends on: (1) *PROPER SURFACE PREPARATION,* (2) a good, durable paint, (3) good workmanship, (4) adequate drying and aging and (5) proper maintenance (through periodic inspection and spot, partial or complete removal of old paint and repainting as necessary).

A tank's interior coating will generally protect the interior for a three- to five-year period, depending on local conditions. Routine inspection is the best way to determine when a tank requires maintenance. New tanks or newly painted tanks should be inspected after one year of use. Otherwise, a tank should be drained, cleaned and inspected every one or two years, depending on local conditions. Two types of inspections can be made:

1. A visual inspection, which is made from the roof hatch with the water level lowered to about half full or less; and
2. A detailed inspection which is accomplished by draining the tank, washing it and then inspecting the interior coating.

A visual inspection may be made in the odd numbered years and a detailed cleaning and inspection may be made in the even numbered years. For example, first anniversary (after painting) — visual inspection, and secondary anniversary — complete cleaning and inspection.

The ideal time of the year to take a storage facility out of service for complete cleaning and inspection is during the period of lowest water consumption. For most water utilities in warmer climates, this will be during the period from October to April. However, this time period will vary depending on the climate and seasonal water demands. In very cold climates storage facilities are not taken out of service and painted in the winter.

When a tank is to be taken out of service, coordination and planning are necessary so that the distribution system will be able to meet the water demands of its consumers. Here are some steps that may be followed for the draining of a storage facility for complete cleaning and inspection:

1. Make sure provisions are made to supply adequate water to the distribution system during shutdown. Be sure that customers who are most affected by the loss of available water from the tank in question will not experience shortages of water or inadequate pressures;
2. Secure (block) inlet line so that no water may enter while the tank is out of service for maintenance;

3. Draw the tank down until there is about one foot (0.3 m) of water left covering the bottom of the tank;
4. Secure (block) the discharge line so that no water will be used from the tank while it is being cleaned;

SAFETY NOTICE

Before anyone ever enters a tank for any reason, these safety procedures must be followed:

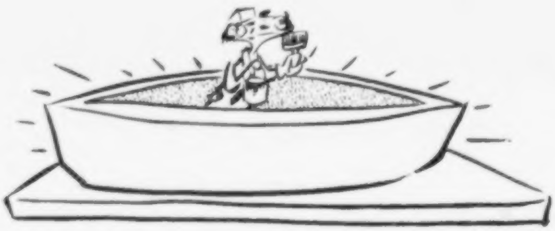
1. Test the atmosphere in the tank for toxic and explosive gases and for adequate oxygen. Contact your local safety equipment supplier for the proper types of atmospheric testing devices. These devices should have alarms which are activated whenever an unsafe atmosphere is encountered.
2. Provide adequate ventilation, especially when painting. A self-contained breathing apparatus may be necessary.
3. All persons entering a tank must wear a safety harness.
4. One person trained in tank rescue procedures, safety and first aid must remain at the tank entrance observing the actions of all people in the tank. An additional person must be readily available to help the person at the tank entrance with any rescue operation.

5. Collect a sample of the water remaining in the tank. Also collect a sample of silt/mud from the tank bottom for biological analysis. Analyze the mud/silt for snails and worms. If snails and/or worms are present, try to determine the source and eliminate it;

6. Drain and dispose of the remaining water and silt/mud;
7. Wash the interior tank walls with a water hose and brushes;
8. Inspect interior coating. Look for flaking, peeling, and rust.

The tank's interior inspection should be done by you or by a representative of a professional tank cleaning and painting service company. If you plan to hire someone to clean and recoat your tank, the following suggestions are recommended:

1. Verify the potential contractor's credentials and experience,
2. Ask for references, and
3. Contact the references for their recommendations.



If substantial flaking, peeling or rust are noted during inspection, the tank's interior should be prepared for repainting.

Preparing a tank's interior for repainting is a very important step if the new coat is to be of any value. Sand blasting is recommended. A brush-off blast (*SSPC #7)[17] may be used when minor deterioration has occurred. Where extensive deterioration is present, the near-white blast (*SSPC #10)[17] is recommended. Clean up the sand and wash down the interior of the tank to remove any particles of sand. The tank is now ready for painting.

There are many interior paint and coating systems that can be used in water storage tanks. They are divided into two basic categories: (1) long-life coatings, and (2) short-life coatings. A short-life coating is any paint or material that will protect the interior surface of a tank up to approximately six years. A long-life coating is a coating or material that can protect the interior surface for up to ten years and possibly longer. Long-life coatings will cost from 30 to 50 percent more than a short-life coating. Since a long-life coating may last up to three times longer than a short-life coating, a long-life coating can reduce your maintenance cost over a period of 10 to 20 years.

Care must be used in the selection of the tank's interior coating. Coatings fall into the category of *INDIRECT ADDITIVES* to the potable water supply and must be of an appropriate quality for this use. Accordingly, they must be non-toxic, must not release organic or inorganic compounds to the surrounding water in toxicologically (poisonous) significant amounts and must not impart objectionable tastes or odors to the water.

Many states require that paints and coatings used in potable water systems be approved by the state. The U.S. Environmental Protection Agency (EPA) provides guidance to states regarding the acceptability of paints and coatings for use in potable water service through the Office of Drinking Water (ODW) additives advisory program. Information on whether particular products have been successfully evaluated by EPA or a state can be obtained from your state health department, the EPA regional office or the EPA-ODW. Additionally, paints and coatings approved for use by the Food and Drug Administration (FDA) for continuous contact with aqueous (watery) foods as defined in Federal Regulations (21 CFR) are generally acceptable for use in potable water systems.

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[17] *Steel Structure Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213.*

The paint or coating should also meet AWWA Specifications.[18] Products which contain lead or *PCB's*[19] are not recommended for potable water use according to recommendations from the Additives Evaluation Branch of EPA's Office of Drinking Water. Coatings using trichloroethylene and tetrachloroethylene should be avoided also.

The best method of applying a coat of paint is by spraying. The cross-spraying method should be used. Spray an area to be painted with horizontal strokes. After the first area has been painted (a 6-foot (2 m) wide section with one coat), move to one side of the first area. Spray another 6-foot (2 m) wide section. Spray three feet (half) of the original section and three feet of a new, unpainted area. Continue this procedure all the way around the tank. Repeat this procedure using vertical strokes and again overlapping half a section every time. This method not only provides an adequate film thickness, but also reduces the chances of holidays (unpainted spots).

Drying time is of prime importance, especially if the paint job is going to be effective. *ALWAYS* assume that a tank's interior does not have sufficient ventilation. A forced-draft ventilation procedure should be used to dry (cure) the coating on a tank's interior. This ventilation will help speed up the drying time. Thorough drying is critical if the paint is to adhere (stick) properly to the tank's interior walls. If drying time is insufficient, problems with tastes and odors or the leaching of potentially toxic materials may occur. To be on the safe side, you may wish to double the drying (curing) time recommended by the paint manufacturer.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 46.

2.4A What is preventive maintenance?

2.4B What is corrective maintenance?

2.4C The time interval for painting the outside of steel tanks depends on what factors?

2.4D During what time of the year should a water storage facility in a warm climate be taken out of service for complete cleaning and inspection?

2.4E How is the interior surface of a tank prepared for repainting?

2.42 Corrosion Control[20]

Corrosion may occur either on the inside or outside of the metal surface of a storage facility. Many factors influence the rate of corrosion. The warmer the water, the faster the chemical corrosion reactions. If a water is corrosive, high water velocities will cause rapid pipe deterioration but with little metal pick up. When water velocities are low, there is a longer contact time between the water and the pipe and there could be a higher metal pick up (consumer complaints of red or dirty water). When two different metals come in contact, the difference in electrical potential causes a flow of current (electrons) which results in corrosion.

Substances in the water also influence the rate of corrosion. Dissolved oxygen in the water can increase corrosion rates. Carbon dioxide lowers the pH of a water which makes it more corrosive. Dissolved minerals (salts) in a water increase the rate of corrosion. Sulfate reducing bacteria can cause increased corrosion.

When waters from different sources and of considerably different chemical content are mixed, the formation of a scale or coating may result. However, when a hard water is replaced with a soft water, corrosion will often result because the scale (protective coating) is dissolved by the soft water.

Painting either the outside or inside of a tank is a form of corrosion control. Usually when one thinks of corrosion control, interior corrosion or metal corrosion comes to mind. A coat of paint is the least expensive type of corrosion control; it is the most important part of any corrosion control program.

Other methods of corrosion control include:

1. Metallic coatings such as zinc or aluminum to protect tank metals such as steel or aluminum (outside coating);
2. Non-metallic coatings to protect tank metals. Appropriate coatings include coal tar enamels (bituminous), asphaltics, cement mortar, epoxy resins, vinyl resins and paints, coal tar-epoxy enamels, inorganic zinc, silicate paints and organic zinc metals (be sure that any coating you use has been approved for use in potable water);

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[18] *D102-78 AWWA STANDARD FOR PAINTING STEEL WATER STORAGE TANKS. See Section 2.9, "Additional Reading," for ordering information.*

[19] *PCBs or* ***P****oly****c****hlorinated* ***B****iphenyls. A class of organic compounds that cause adverse health effects in domestic water supplies.*

[20] *For additional information on the causes of corrosion and methods of corrosion control, see Chapter 8, "Corrosion Control," in WATER TREATMENT PLANT OPERATION, Volume I, in this series of manuals*

3. Chemicals could be added during the treatment of water which would deposit a protective coating or film on the tank's metal (calcium hydroxide (lime), sodium carbonate (soda ash), zinc orthophosphate, and silicate compounds, for example); and
4. Electrical control *(CATHODIC PROTECTION*[21]*)*.

CALCIUM
CARBONATE
sodium hexametaphosphate
SILICATE
COMPOUND

Rarely is one of these methods used by itself as a means of controlling corrosion. The addition of chemicals to water in order to deposit a protective coating is an excellent method of controlling corrosion. Any substance which promotes film formation on the surface to be protected when added to water is known as a corrosion inhibitor. Lime, soda ash and caustic soda (sodium hydroxide) are chemicals that are used to help control corrosion. When added to water these chemicals will increase the pH. At a certain pH depending on the temperature, total dissolved solids, calcium concentration and alkalinity level of the water, the calcium carbonate equilibrium will be reached. For any pH above the equilibrium level, a thick coating of calcium carbonate will form on surfaces exposed to the water. This coating will protect the surfaces from corrosion. As long as the pH remains above the equilibrium level, the coating will not dissolve and will provide protection against corrosion.

Chemical inhibitors reduce the rate of corrosion by preventing dissolved oxygen from reaching the cathodic areas, thus inhibiting the rate-controlling cathodic reactions. Chemical inhibitors are applied to water entering a tank or pipeline by means of a continuously operated pump. The chemicals added to the water deposit a chemical film on the insides of the pipe or tank, thus protecting the interior. Sodium hexametaphosphate (polyphosphate) compounds are commonly used because they combine with (tie up) a variety of *IONS*[22] including iron, manganese and calcium, thus preventing their buildup as rust or scale. Polyphosphate is available either in a dry or liquid form. The liquid form is becoming more widely used because less equipment is needed for its application than for the dry form.

While polyphosphate compounds are commonly used, special pumps and safety equipment must be used for safe and proper application. Phosphate is usually fed at a rate of not more than five mg/*L*. This chemical is costly and monitoring the feed rate and resulting concentration in the potable water is essential. Chemical control methods should be used as a supplement to the proper choice of metals and metallic and non-metallic coatings.

Cathodic protection (Figure 2.13) must not be regarded as a substitute for the use of a proper interior coating nor the application of inhibitors, but should be used if necessary to supplement the other methods. Cathodic protection uses an electrical system for the prevention of corrosion and pitting of steel and iron surfaces in contact with water. A low-voltage current is made to flow through a liquid or soil in contact with the metal in such a manner that the external *ELECTROMOTIVE FORCE*[23] renders the metal structure *CATHODIC*[24] and transfers the corrosion to auxiliary sacrificial *ANODIC*[25] parts used for the purpose of corroding instead of the water storage facility. The key to successful use of cathodic protection is the replacement of the sacrificial anodes (usually made of magnesium or zinc) when they have been corroded away. These anodes (sacrificial) should be inspected (weighed to determine loss in weight due to corrosion) at least yearly and replaced when necessary.

Cathodic protection systems not only prevent corrosion, but can reduce time and money spent cleaning and painting. Also the time required for a storage facility to be out of service for maintenance can be reduced. Cathodic protection of a water storage facility is effective only for those areas that are covered by water. The need for a high-quality coating is not eliminated by the installation of a cathodic protection system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 47.

2.4F List five methods of corrosion control.

2.4G What is a corrosion inhibitor?

2.4H What is the key to a successful cathodic protection program?

2.43 Disinfection[26]

Disinfection is the destruction of disease-producing organisms. New storage facilities and facilities which have been repaired, cleaned, or had cathodic protection installed must be disinfected. Always disinfect water storage facilities whenever there has been any opportunity for contamination.

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[21] *Cathodic Protection (ca-THOD-ick). An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. A low-voltage current is made to flow through a liquid (water) or a soil in contact with the metal in such a manner that the external electromotive force renders the metal structure cathodic. This concentrates corrosion on auxiliary anodic parts which are deliberately allowed to corrode instead of letting the structure corrode.*

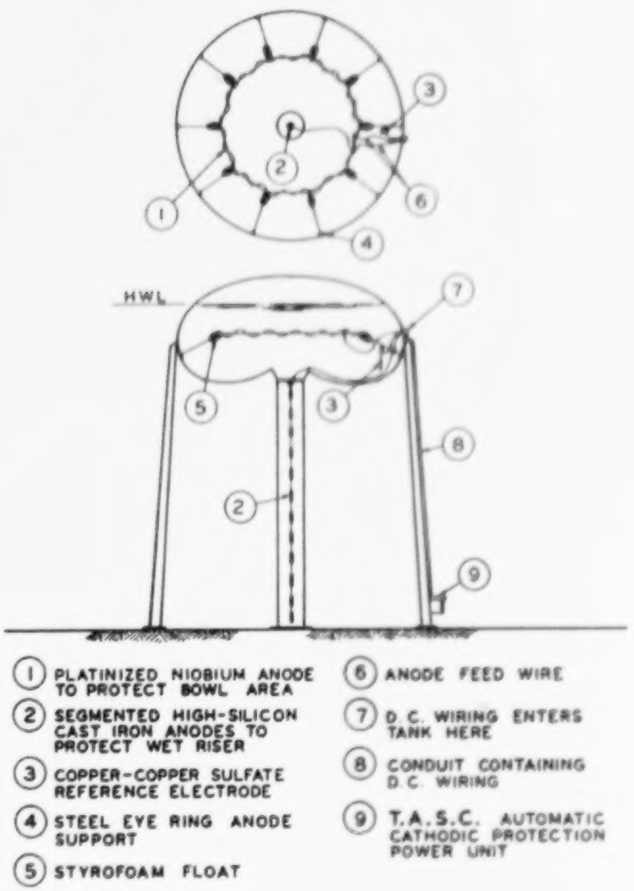
[22] *Ion. An electrically charged atom, radical (such as* SO_4^{2-}*), or molecule formed by the loss or gain of one or more electrons.*

[23] *Electromotive Force (E.M.F.). The electrical pressure available to cause a flow of current (amperage) when the electrical circuit is closed.*

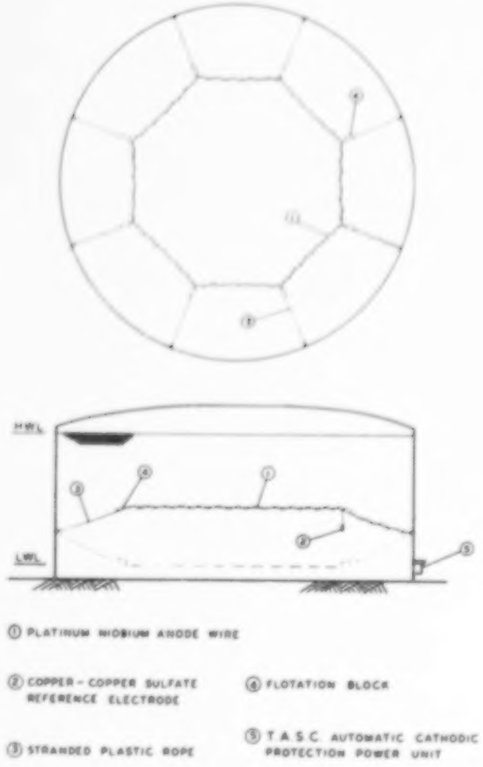
[24] *Cathode (KA-thow-d). The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations).*

[25] *Anode (an-O-d). The positive pole or electrode in an electrolytic system, such as a battery. The anode attracts negatively charged particles or ions (anions).*

[26] *For additional information on disinfection, see Chapter 6, "Disinfection."*


HWL
① PLATINIZED NIOBIUM ANODE TO PROTECT BOWL AREA
② SEGMENTED HIGH-SILICON CAST IRON ANODES TO PROTECT WET RISER
③ COPPER-COPPER SULFATE REFERENCE ELECTRODE
④ STEEL EYE RING ANODE SUPPORT
⑤ STYROFOAM FLOAT
⑥ ANODE FEED WIRE
⑦ D.C. WIRING ENTERS TANK HERE
⑧ CONDUIT CONTAINING D.C. WIRING
⑨ T.A.S.C. AUTOMATIC CATHODIC PROTECTION POWER UNIT

Elevated Water
Storage Tanks


HWL
LWL
① PLATINUM NIOBIUM ANODE WIRE
② COPPER - COPPER SULFATE REFERENCE ELECTRODE
③ STRANDED PLASTIC ROPE
④ FLOTATION BLOCK
⑤ T.A.S.C. AUTOMATIC CATHODIC PROTECTION POWER UNIT

Ground-Level Water
Storage Tanks

PERMANODE ANODE SYSTEM

The **only** proven permanent anode system for water tanks subject to winter icing conditions. Ten or more years of continuous cathodic protection can be expected instead of the 9-10 months previously provided by aluminum anode systems. This provides even greater economics to water tank owners in Northern climates.

Fig. 2.13 Cathodic protection systems
(Courtesy of Harco Corporation, Medina, Ohio)

Liquid chlorine (or gas), calcium hypochlorite, or sodium hypochlorite are commonly used as disinfectants. There are several methods which are used to disinfect a water storage facility. *NOTICE:* Before anyone enters a water storage facility for any reason, follow the safety procedures listed under the *SAFETY NOTICE* on page 35.

WARNING

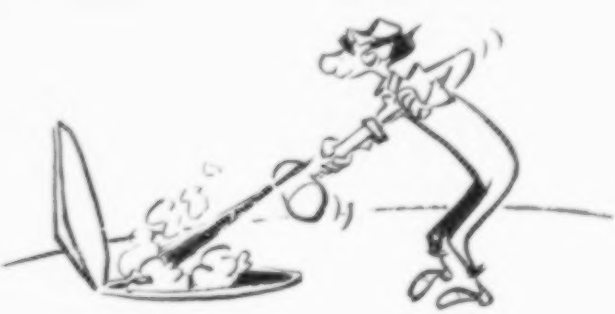
BEFORE attempting to spray the interior of a tank, be sure there is adequate ventilation. If adequate ventilation is not available, the person doing the spraying must use a self-contained breathing apparatus.

ALWAYS wear protective clothing when spraying a tank interior. Protective clothing should consist of a rubberized suit (rain gear — rubber pants and coat), rubber boots, gloves, hat and a face shield.

Whenever anyone enters a tank, they must wear a safety harness for rescue purposes. Someone must be at the tank entrance to observe the person in the tank and also to hold the safety rope attached to the harness being worn by the person in the tank. A method of communication using tugs on the safety rope must be established *BEFORE* anyone enters a tank. For example, one tug may mean help and two tugs means everything is OK.

In addition to the back-up person at the tank entrance, a third person must be readily available to assist the person at the tank entrance.

NO ONE should enter a tank for any reason or under any circumstances without two people standing by for rescue purposes. Too often someone has entered a tank to rescue a friend and died also.



Spray or brush the interior of the storage facility with 200 mg/*L* chlorine solution. The chlorine solution can be mixed in a crock or small tank. The application can be accomplished by using garden hoses with nozzles and pressure can be provided by a gasoline-driven pump. (A 200 mg/*L* chlorine concentration can be uncomfortable to work with inside of a storage facility. *ALWAYS PROVIDE ADEQUATE VENTILATION WHENEVER ANYONE IS INSIDE A TANK FOR ANY REASON.* The amount and type of ventilation depends on the situation.)

To prepare a 200 mg/*L* solution using sodium hypochlorite, let's use a 100-gallon crock of water and assume that the sodium hypochlorite has five percent *AVAILABLE CHLORINE.*[27] Sodium hypochlorite usually is available in the range from 5 to 15 percent available chlorine. The sodium hypochlorite must be thoroughly mixed with water to produce the chlorine solution.

FORMULAS

To determine amount of sodium hypochlorite needed in pounds, you may use the following formula:

$$\text{Hypochlorite, lbs} = \frac{\left(\text{Volume of Water, Million Gallons}\right)\left(\text{Chlorine Conc., mg}/L\right)\left(8.34\ \text{lbs/gal}\right)100\%}{\text{Available Chlorine, \%}}$$

Also, you should know that

100 gals of water = 0.0001 MG of water, and

1 gal of water = 8.34 lbs.

These are constants you should remember.

EXAMPLE 2

Prepare a 200 mg/*L* solution of chlorine using a 100-gallon crock (0.0001 million gallons) and a sodium hypochlorite solution containing five percent available chlorine. How many gallons of hypochlorite should be added to the 100 gallons of water in the crock?

Known		**Unknown**
Chlorine Conc., mg/*L*	= 200 mg/*L*	Hypochlorite, gallons
Vol. of Water, MG	= 0.0001 MG	
Available Cl, %	= 5%	

1. Calculate the pounds of hypochlorite needed to produce a chlorine concentration of 200 mg/*L*.

$$\begin{aligned}\text{Hypochlorite, lbs} &= \frac{\left(\text{Volume of Water, Million Gallons}\right)\left(\text{Chlorine Conc., mg}/L\right)\left(8.34\ \text{lbs/gal}\right)100\%}{\text{Available Chlorine, \%}}\\ &= \frac{(0.0001\ \text{MG})(200\ \text{mg}/L)(8.34\ \text{lbs/gal})(100\%)}{5\%}\\ &= 3.34\ \text{lbs}\end{aligned}$$

2. Determine the gallons of 5 percent sodium hypochlorite to be added to the 100 gallons of water.

$$\begin{aligned}\text{Hypochlorite, gallons} &= \frac{\text{Hypochlorite, lbs}}{8.34\ \text{lbs/gal}}\\ &= \frac{3.34\ \text{lbs}}{8.34\ \text{lbs/gal}}\\ &= 0.40\ \text{gallons}\end{aligned}$$

After tank has been sprayed with the hypochlorite solution, allow the tank to stand unused for at least 30 minutes before filling. Fill the tank with distribution system water that has been treated with chlorine to provide a chlorine residual of 8 mg/*L*. Let the water in the tank stand for 3 to 6 hours. Take a bacterial sample of tank water in a sterile container and test for coliform bacteria (see Chapter 7, "Laboratory

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[27] ***Available Chlorine.*** *A measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine when compared with that of elemental (liquid or gaseous) chlorine.*

Procedures," in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE*). Be sure to add enough sodium thiosulfate to the sampling bottle before it is sterilized to neutralize all chlorine in the water. After a sample is collected, shake the bottle and test to be sure there is no chlorine residual. After bacteriological tests prove negative (no coloforms), steps can be taken to put the tank back into service.

Another method of disinfecting a water storage tank is to fill the tank with water with a high enough chlorine concentration to produce a chlorine residual of 3 mg/*L*. This method of disinfection is used after the tank has been cleaned and the cathodic protection device has been serviced as necessary. The tank is inspected to be sure that all equipment and tools have been removed. Sufficient chlorine is then applied to the water entering the tank to end up with 3.0 mg/*L* of chlorine residual. The water in the tank is sampled for bacteriological tests 24 hours after the tank has been filled. After bacteriological tests prove negative (no coliforms), the tank is put back in service.

EXAMPLE 3

How many pounds of chlorine gas are needed to disinfect a one-million gallon water storage tank if desired chlorine dose is 3.0 mg/*L*? Assume that there is no chlorine demand in the water used to fill the tank. Therefore, we will end up with a 3.0 mg/*L* chlorine residual.

Known		Unknown
Chlorine Conc., mg/*L*	= 3.0 mg/*L*	Chlorine Gas, lbs
Vol. of Water, MG	= 1.0 MG	

1. Calculate the pounds of chlorine gas needed to produce a 3 mg/*L* chlorine residual in a one-million gallon storage tank.

$$\begin{aligned}\text{Chlorine Gas, lbs} &= \left(\begin{matrix}\text{Vol. of Water,}\\ \text{Mil. Gallons}\end{matrix}\right)\left(\begin{matrix}\text{Chlorine Conc.,}\\ \text{mg}/L\end{matrix}\right)(8.34\ \text{lbs/gal})\\ &= (1.0\ \text{MG})(3.0\ \text{mg}/L)(8.34\ \text{lbs/gal})\\ &= 25.0\ \text{lbs chlorine gas}\end{aligned}$$

A chlorinator can be installed to add chlorine to the water entering the storage tank or a separate chlorine solution feed line can be used to convey the chlorine solution to the one-million gallon storage tank. Weigh the 150-pound chlorine cylinder at the start. After the chlorine cylinder weight has dropped by 25 pounds, you will know you have added enough chlorine. Be sure to mix the chlorine solution with the water filling the tank so the chlorine solution will be evenly mixed throughout the tank.

Another acceptable method of disinfecting a water storage tank is to fill the tank with potable water which has been treated to provide a chlorine residual of at least 10 mg/*L* after a six-hour contact period. This six-hour period is sufficient when chlorine or sodium hypochlorite has been applied to the water entering the tank at a uniform rate by the use of a portable chlorinator or a chemical feed pump (hypochlorinator). When sodium hypochlorite (a liquid) or calcium hypochlorite (a tablet) has been used either by pouring the liquid into the storage facility or by use of tablets which are dissolved by the water flowing into the tank, the water should have a 10 mg/*L* chlorine residual after a 24-hour contact period.

The last acceptable method described here requires that enough chlorine be added to the water to produce 50 mg/*L* of available chlorine when the storage tank is approximately five percent full. This solution of chlorine and water must be held in the tank for at least six hours. After six hours the storage tank is filled to the overflow level with potable water and held at this level for at least 24 hours.

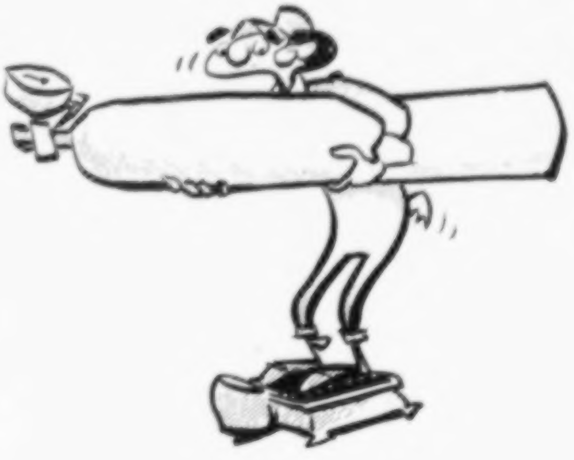
After a water storage tank has been disinfected, the remaining mixture of chlorine and water must be properly disposed of. Any water with a chlorine residual of 2 mg/*L* or more must be either diluted with additional water or the chlorine properly neutralized before being discharged. Chlorine neutralization chemicals include sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), sodium sulfite (Na_2SO_3), or sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$). The amount of neutralizing chemical will depend on the chlorine residual and the type of neutralizing chemical. By mixing various amounts of a neutralizing chemical with the water in the tank, you can determine the amount of chemical which will just neutralize all of the chlorine residual.

A highly chlorinated water *MAY* be discharged to a sanitary sewer provided *PERMISSION IS OBTAINED* from the local agency which operates the wastewater collection system and treatment facilities. If the chlorinated water is discharged slowly and there is no opportunity for *BACKFLOW*[28] or *BACKSIPHONAGE*[29] between the wastewater collection system and the water storage tank, this method *MAY* be approved.

Chlorinated waters should not be discharged to any surface waters (storm drains, rivers, lakes) without obtaining approval of the appropriate water pollution control agencies.

NOTE:

1. When disinfecting a water storage facility for the first time (a newly purchased or constructed tank), the chlorine residual should be 50 mg/*L* (instead of 3 mg/*L* when placing a tank back in service) for 24 hours.



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[28] *Backflow. A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes or storage tank of a potable water supply from any source or sources other than the intended source. Also see BACKSIPHONAGE.*

[29] *Backsiphonage. A form of backlow caused by a negative or below atmospheric pressure within a water system. Also see BACKFLOW.*

2. Small water storage tanks are commonly disinfected with a chlorine dosage of 50 mg/*L*. A chlorine residual of at least 10 mg/*L* must remain at the end of the 24-hour disinfection period. Large clear wells are usually disinfected with chlorine residuals of 3 mg/*L*. AWWA's standards for disinfection of tanks (see Section 2.9, AWWA Standard D105-80, lists three disinfection methods. The important point is, *IF YOU RECEIVE NEGATIVE COLIFORM TEST RESULTS (NO COLIFORMS PRESENT), YOU HAVE ADEQUATELY DISINFECTED THE STORAGE FACILITY.*

3. Whenever you collect a sample for a bacteriological test (coliforms), be sure to use a sterile plastic or glass bottle that contains sufficient sodium thiosulfate to neutralize all of the chlorine residual.[30] The amount of sodium thiosulfate depends on whether the sample contains a chlorine residual of 3 mg/*L* or 50 mg/*L*. Add sufficient sodium thiosulfate to the sample bottle, sterilize the bottle and then collect the sample for the coliform test. After the sample has been collected, shake the sample and measure the chlorine residual. If there is a chlorine residual, carefully add more sterilized sodium thiosulfate, shake sample, measure the chlorine residual and continue repeating the procedures until there is no chlorine residual. A good practice is to discuss the project you are working on with your lab and have the lab sterilize sufficient sodium thiosulfate in the sample bottle when the bottle is sterilized.

Chlorine gas is used with large capacity storage tanks because of the relatively low price of chlorine. Small storage tanks are treated with sodium hypochlorite or calcium hypochlorite. The guideline for use of chlorine gas versus sodium hypochlorite is: for any tank over 100,000 gallons (380 cu m) capcity, use chlorine gas; for any tank below 100,000 gallons (380 cu m) capacity, sodium hypochlorite may be easier to use.

After water in a storage tank has negative bacteriological results (no coliforms), it may be returned to service. To return a storage tank to service:

1. Empty the tank of chlorinated water. Discharge to a storm drainage system may be acceptable if you have a small volume of water with a high chlorine residual and there is sufficient dilution water in the drainage system. If you have a large volume of water with a low chlorine residual, gradually release this water into the distribution system, being careful not to produce too high a chlorine residual at a consumer's tap. Other alternatives include allowing the tank to sit while chlorine dissipates or adding sodium bisulfite to reduce the residual.
2. Open outlet valve from tank to the distribution system.
3. Make sure inlet valve to tank is open so that tank will *FLOAT ON SYSTEM*[31] (drawn down and fill as needed).
4. If appropriate, remove interim method of providing water to distribution system (no longer needed because tank is back in service).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 47.

2.4I List the three common types of disinfectants used to disinfect water storage facilities.

2.4J What are two methods of disinfecting a water storage tank?

2.4K What is the guideline for determining whether chlorine gas or sodium hypochlorite is used to disinfect a water storage tank?

2.44 Concrete Storage Facilities

Maintenance of concrete water storage facilities is very similar to steel tanks. Vents and overflows must be properly screened to keep out birds, rodents and insects. After the first year in service and every other year thereafter the facility should be drained, cleaned and inspected. Special attention must be given to cracks which may allow either leakage or the inflow of contaminated water. Any material used for painting, coating or repairs must be approved for use in potable water systems. New facilities and old facilities after inspection and repair must be properly disinfected. *ALWAYS FOLLOW SAFE PROCEDURES BEFORE ENTERING AND WHENEVER YOU MUST ENTER A CONCRETE STORAGE FACILITY (CONFINED SPACE).*

Whenever you inspect a concrete storage facility, be sure the facility is secure from vandals and unauthorized persons. Inspect the access to the facility and cover to be sure contaminated water cannot get inside. Look at the surface of the water to be sure there is no floating debris or dead birds or rodents.

WARNING: Never attempt to empty any underground tank when the water table is high. If the water table is high, an empty tank could float to the water surface like a cork. When this happens the tank could crack and inlet and outlet pipes could be damaged.

2.45 Grounds

Storage facility grounds should be landscaped and kept clean. Well-kept landscaping is not only aesthetically desirable, but gives everyone the impresson of a well-run operation.

2.46 Frozen Distribution Reservoirs by Dick Krueger

When subzero temperature conditions exist for several days, ice formation may occur in both underground and elevated distribution storage reservoirs. In underground reservoirs ice formation is usually limited to surface ice on top of the water. In elevated tanks, icing may be more severe and thick accumulations on sidewalls have been observed. Damage to walls and structures may result from these accumulations of ice or falling ice inside or outside of the tank. Interior ladders, for example, may become distorted and either partially or totally tear away from the mounting brackets. As water freezes, expansion pressure may separate steel plates or panels and the tank diameter may be altered resulting in interior coating failure.

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[30] *A 120 mL sample bottle requires 0.1 mL of ten percent sodium thiosulfate ($Na_2S_2O_3 \cdot 5\ H_2O$) to neutralize about a 15 mg/L chlorine residual.*

[31] *Float On System. A method of operating a water storage facility. Daily flow into the facility is approximately equal to the average daily demand for water. When consumer demands for water are low, the storage facility will be filling. During periods of high demands, the facility will be emptying.*

Ice formations can be minimized by continuously fluctuating reservoir water levels. The pumping and flow rates into and out of the reservoir should be adjusted to allow continuous water circulation and to prevent ice from becoming attached to walls and columns, thus being suspended above the surface level of the water. The use of automatic controls may have to be temporarily suspended, particularly during low consumption hours when water levels remain constant for extended periods. Storage tanks can also be equipped with a small compressor for tank bubbler operation in order to circulate water in the tank and prevent the surface from freezing over.

In most cases the inflow of new water pumped into a reservoir coupled with the usual drawdown results in sufficient circulation to keep ice formation to a minimum. In elevated tanks, the water level should be varied by 50 percent every 24 hours. Water may have to be drained from a tank using a hydrant if pumping schedules, based on reduced winter water demand, do not allow continuous circulation in the tank. Freeze-up in elevated reservoirs may also be reduced by the installation of a frost jacket consisting of three inches (8 cm) of insulation covered with a metal banded jacket. In underground reservoirs, 25 percent fluctuations in water levels every 24 hours are sufficient to minimize icing. In arctic and subarctic areas, circulating water systems which continuously pump and reheat the water in the system are required to prevent severe icing. Water level indicators, floats or electric sensors may be damaged when icing occurs. Float assemblies are highly susceptible to ice damage including snapped steel float cables, crushed interior metal floats and destruction of float guide pulleys or guide mounts. In reservoirs subject to recurrent ice formations, pressure gage devices are recommended as an alternative to float assemblies. Level measuring devices as well as level transmitters should be equipped with heaters to prevent damage or malfunction.

Air or overflow vents may also become obstructed by accumulations of ice and snow. The vent screens should be checked routinely in order to prevent blockage and insure a free air circulation. In elevated reservoirs, the altitude valve which controls inflows must also be kept free of ice and snow.

Ice buildup on the outside of an elevated tank reservoir can erode paint surfaces, increase the load on structural supports and create a falling ice hazard. Outer surface ice, which forms as a result of overflows or tower leakage, has actually caused some elevated tanks to collapse. In the Fall the tower structure should be carefully inspected for structural defects and intentional overflows should be avoided when ice formation is possible.

If an excessive ice buildup inside an elevated distribution reservoir has occurred or the tank malfunctions due to icing, a number of steps can be taken to restore operation. The affected tank should be "valved off" and the distribution system pressurized using alternate means such as other storage tanks. Pressure relief valves should be attached at strategic locations if high pressure has built up. The pressure valves can be attached to fire hydrants and excess water can then be wasted to a storm sewer. All water pumps should be operated manually. The ice can be most effectively thawed using a steam generator equipped with 65 to 100 yards (60 to 90 meters) of hose. The hose can be inserted into one of the access hatches in the tank to thaw the ice. Usually, one day of steam thawing is adequate to restore water circulation in the tank. Any leaks or damage to the tank should be repaired before placing the reservoir back into service.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 47.

2.4L Does the maintenance of concrete water storage facilities differ much from steel tanks?

2.4M What type of water level indicators could be damaged due to icing in a storage tank?

2.4N What problems can be caused by ice buildup on the outside of an elevated tank?

2.5 RELATED EQUIPMENT

2.50 Booster Pumps (Figure 2.14)

A booster pump is used to increase the pressure in the mains on the discharge side of the main pumps or *TO SUPPLY WATER TO AN ELEVATED STORAGE TANK.* Booster pumps are also used to supply water to a service area at a higher elevation. Most booster pumps are connected with a solenoid switch to the altitude valve on the tank.

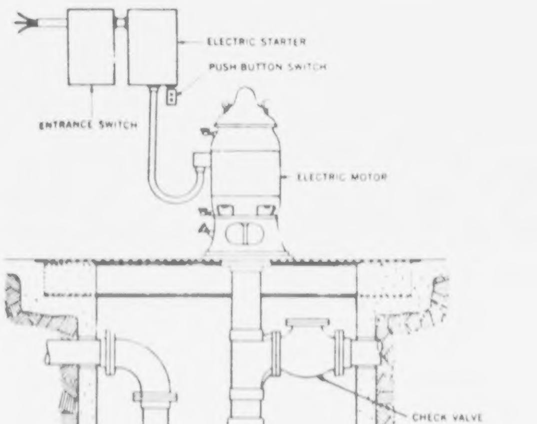

Fig. 2.14 Booster pump

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

When water falls below a predetermined amount, the solenoid is actuated and the booster pump begins to pump water to the tank. The operation and maintenance of the booster pump is critical to the effective operation of the elevated tank and the system which it serves.

Booster pumps are centrifugal pumps and care should be used in their operation. You need only be concerned with two critical points: installation and alignment. If the initial installation and the alignment are properly done, the pump should give few problems and require little maintenance other than routine checking of the packing and lubrication of bearings. Table 2.2 outlines procedures for troubleshooting centrifugal pumps.

2.51 Regulator Stations

A regulator station's main function is to reduce pressure and to maintain an even, acceptable pressure downstream from a high pressure system. Regulator stations are frequently found in a water system using pumps or on a gravity system where the reservoir may have extreme pressure head (high above the service area of use). Regulator stations consist of a series of valves which reduce high pressures to lower, more acceptable working pressure. Water pressure over 100 psi (690 kPa or 7.0 kg/sq cm) should be regulated to a safe, usable pressure of 60 to 90 psi (414 to 621 kPa or 4.2 to 6.3 kg/sq cm). Where the excessive water pressure is not regulated, a pressure-reducing valve will be required on each consumer's service so that a safe, usable pressure can be obtained.

The operation and maintenance of the valves in the regulator station are the key to its proper operation. Valves should be routinely exercised (operated). Also, all valves in a regulator station should be exercised (operated) at their lowest and highest pressure settings to see whether the diaphragms (seals and gaskets) are holding and not leaking. This should be done routinely at least once a month. Valves should be inspected and overhauled at least annually. Water high in calcium may cause deposits which make it necessary to exercise the valves more frequently than this.

2.52 Gages

Gages are instruments which measure pressure. If gages are used in the correct locations, they can be useful to you as an indicator of your water system pressures. Gages are commonly used on the discharge side of pumps. These pressure readings could help indicate the efficiency of your pumps or loss of water pressure in your mains. Gages also are used in the operation and maintenance of regulator stations.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 47.

2.5A What is the purpose of a booster pump?

2.5B What two points are critical to the successful operation of a booster pump?

2.5C Regulator stations are used for what purpose?

2.5D Where are gages usually located?

2.6 RECORDS

Records provide necessary data for the effective operation of a water system. Records of equipment should include the nameplate data, date of installation, start-up data, failures and any type of service performed on the equipment. Results of tank inspections, condition of tank, maintenance performed, and all repairs or corrective action must be recorded. A list available to all involved operators of particular problems and the means used to resolve each problem is an essential part of any recordkeeping system. Performance data must be kept on your corrosion control program. Also, the engineering plans and specifications of each type of tank structure in your system are part of your permanent records.

2.7 SAFETY

SAFETY IS EVERYONE'S RESPONSIBILITY FROM THE HEAD OF THE WATER UTILITY AGENCY TO EVERY WATER SUPPLY SYSTEM OPERATOR. However, you are the most important person when the subject of safety comes up. You have a dual responsibility. You are required to use safety equipment provided by your agency and you should be watchful for unsafe conditions and report them to your supervisor.

In working around water storage facilities, the following safety hazards should be of personal concern to you:

1. Make sure the area around the storage facility is clean and clear of debris.
2. Use care when climbing storage facility ladders or stairways. When using ladders, use a ladder safety belt. Remember: only one person at a time on a ladder. When a ladder is not in use, have the ladder guard in place so that unauthorized persons will not be able to use it. Be very careful using safety climbing devices that are equipped with a cable because cables can fail due to vibrations caused by winds.

   If a stairway is used to climb up to the storage facility, safety treads should be placed on stairs and a hand rail should be used.
3. When entering a storage facility for inspection, test the atmosphere and make sure you have sufficient ventilation. Monitor the facility before entering to verify that you are not entering an oxygen-deficient atmosphere and that there are no toxic or explosive gases present (especially when applying coatings).

   Make sure adequate ventilation is available during inspection or maintenance in the facility. Use forced-draft ventilation where necessary for safety of personnel.

   Be sure to wear a safety harness. One person must be at the entrance watching you at all times. A third must be readily available to help with rescue operations. For additional information on how to safely enter a storage tank, see Section 7.63, "Confined Spaces."

TABLE 2.2 CENTRIFUGAL PUMP TROUBLESHOOTING CHART[a]

Problem	Possible Causes
Pump does not deliver water	1-4, 6, 11, 14, 16, 17, 22, 23
Insufficient capacity delivered	2-11, 14, 17, 20, 22, 23, 29-31
Insufficient pressure developed	5, 14, 16, 17, 20, 22, 29-31
Pump loses prime after starting	2, 3, 5-8, 11-13
Pumps require too much power	15-20, 23, 24, 26, 27, 29, 33, 34, 37
Stuffing box leaks excessively	1, 24, 26, 32-36, 38-40
Packing has short life	12, 13, 24, 26, 28, 32-40
Pump vibrates or is noisy	2-4, 9-11, 21, 23-28, 30, 35, 36, 41-47
Bearings have short life	24, 26-28, 35, 36, 41-47
Pump overheats and seizes	1, 4, 21, 22, 24, 27, 28, 35, 36, 41

Key to Possible Causes of Operational Difficulties with Centrifugal Pumps

1. Pump not primed.
2. Pump or suction pipe not completely filled.
3. Suction lift too high.
4. Insufficient margin between suction pressure and vapor pressure.
5. Excessive amount of air or gas in liquid.
6. Air pocket in suction line.
7. Air leaks into suction line.
8. Air leaks into pump through stuffing boxes.
9. Foot valve too small.
10. Foot valve partially clogged.
11. Inlet of suction pipe insufficiently submerged.
12. Water-seal pipe plugged.
13. Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form seal.
14. Speed too low.
15. Speed too high.
16. Wrong direction of rotation.
17. Total head of system higher than design head of pump.
18. Total head of system lower than pump design head.
19. Specific gravity of liquid different from design.
20. Viscosity of liquid different from specifications.
21. Operation at very low capacity.
22. Parallel operation of pumps unsuitable for such operation.
23. Foreign matter in impeller.
24. Misalignment.
25. Foundations not rigid.
26. Shaft bent.
27. Rotating part rubbing on stationary part.
28. Bearings worn.
29. Wearing rings worn.
30. Impeller damaged.
31. Casing gasket defective, permitting internal leakage.
32. Shaft or shaft sleeves worn or scored at packing.
33. Packing improperly installed.
34. Incorrect type of packing for operating conditions.
35. Shaft running off center because of worn bearings or misalignment.
36. Rotor out of balance, resulting in vibration.
37. Gland too tight, resulting in no flow of liquid to lubricate packing.
38. Failure to provide cooling liquid to water-cooled stuffing boxes.
39. Excessive clearance at bottom of stuffing shaft and casing, causing packing to be forced into pump interior.
40. Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.
41. Excessive thrust caused by mechanical failure inside pump or by failure of hydraulic balancing device, if any.
42. Excessive grease or oil in antifriction bearing housing or lack of cooling, causing excessive bearing temperature.
43. Lack of lubrication.
44. Improper installation of antifriction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair).
45. Dirt getting into bearings.
46. Rusting of bearings due to water in housing.
47. Excessive cooling of water-cooled bearing, resulting in condensation in bearing housing.
48. Malfunction foot valve.

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[a] WATER DISTRIBUTION OPERATION TRAINING HANDBOOK, No. 20103. Available from AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235. Price to members, $11.50; nonmembers, $14.40.

Safety should be made part of your routine operation. Safety is a way of thinking which can help you operate and maintain your facilities more effectively.

2.8 ARITHMETIC ASSIGNMENT

A good way to learn how to solve arithmetic problems is to work on them a little bit at a time. In this operator training manual we are going to make a short arithmetic assignment at the end of every chapter. If you will work this assignment at the end of every chapter, you can easily learn how to solve waterworks arithmetic problems.

Turn to the Appendix at the back of this manual and read the following sections:

1. OBJECTIVES,
2. A.0 HOW TO STUDY THIS APPENDIX,
3. A.1 BASIC ARITHMETIC,
4. A.2 AREAS,
5. A.3 VOLUMES,
6. A.10 BASIC CONVERSION FACTORS,
7. A.11 BASIC FORMULAS, and
8. A.12 HOW TO USE THE BASIC FORMULAS

Solve all of the problems in Sections A.10, Addition; A. 12, Multiplication; A.13, Division; A.14, Multiplication and Division; A.15, Actual Problems; A.2, Areas (A.20, A.21, A.22, A.23, A.24, A.25 and A.26) and A.3, Volumes (A.30, A.31, A.32, A.33 and A.34) on an electronic pocket calculator. You should be able to get the same answers.

2.9 ADDITIONAL READING

1. *NEW YORK MANUAL*, Chapter 17, "Protection of Treated Water."
2. *TEXAS MANUAL*, Chapter 16, "Storage of Potable Water."
3. *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, No. 20103. Available from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235. Price to members, $13.00; nonmembers, $16.50.
4. *INTRODUCTION TO WATER DISTRIBUTION*, No. 1916. Available from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235, 1987. Price, $27.50.
5. AWWA Standards on Storage. Available from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235.
    a. D101-53[R79]. *AWWA STANDARD FOR INSPECTING AND REPAIRING STEEL WATER TANKS, STANDPIPES, RESERVOIRS, AND ELEVATED TANKS FOR WATER STORAGE*, No. 44101. Price to members, $7.00; nonmembers, $8.50..
    b. D102-78. *AWWA STANDARD FOR PAINTING STEEL WATER STORAGE TANKS*, No. 44102. Price to members, $7.00; nonmembers, $8.50.
    c. D105-80. *AWWA STANDARD FOR DISINFECTION OF WATER STORAGE TANKS*, No. 44105. Price to members, $5.00; nonmembers, $6.50.
6. *WATER SUPPLY, TREATMENT AND DISTRIBUTION* by Rodger Walker. Available from Prentice-Hall Inc., PO Box 500, Englewood Cliffs, New Jersey 0732. Price, $28.95.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 47.

2.6A What information about equipment should be included in your records?

2.7A What safety precautions should be exercised when working around a water storage facility?

DISCUSSION AND REVIEW QUESTIONS

Chapter 2 STORAGE FACILITIES

Please write the answers to these questions in your notebook. The purpose of these questions is to indicate to you how well you understand the material in this chapter.

1. Why must care be exercised whenever large pumps are put on line or taken off line?
2. How can the development of tastes and odors be prevented in storage tanks in a new development with little demand for water?
3. What factors should be checked during the inspection of a continuously operating centrifugal pump?
4. How would you determine if a water storage tank needed cleaning?
5. What is the different between preventive and corrective maintenance?
6. During inspection of a tank, how would you determine if the interior needed repainting?
7. How would you select a paint for the interior of a water storage tank?
8. How would you disinfect a water storage tank after it was taken out of service for inspection?

SUGGESTED ANSWERS

Chapter 2 STORAGE FACILITIES

Answers to questions on page 22.

2.0A The main purpose of a water storage facility is to provide a sufficient amount of water to average or equalize the demand on the water supply system. Also the storage facility is expected to help maintain adequate pressures throughout the entire system.

2.0B The advantages of distribution system storage include:

1. Demands on the source of water, the pumping facilities, and the transmission and distribution mains are more nearly equalized and also the capacities of the tanks and other treatment facilities need not be so great.
2. System flows and pressures are improved and stabilized.
3. Reserve water supplies are provided in the distribution system for emergencies such as fire fighting and power outages.

Answers to questions on page 27.

2.1A The five common types of tanks found in water supply systems are: (1) clear wells, (2) elevated tanks, (3) stand pipes, (4) hydropneumatic tanks, and (5) surge tanks.

2.1B A clear well is used to store filtered water from a treatment plant. The purpose of a clear well is to allow fairly constant water filtration rates. Clear wells store excess water when the demand for water is low and supply additional water when the demand is high.

2.1C The main purpose of an elevated storage tank is to maintain an adequate and fairly uniform pressure to its service zone.

Answers to questions on page 27.

2.2A The selection of the type of storage facility or tank depends on the system's individual needs and the type of terrain where it is to be installed.

2.2B Elevated storage tanks are commonly used to supply adequate pressure to a service area.

Answers to questions on page 29.

2.3A Major system changes such as bigger size main lines and the installation of multiple services can change storage requirements and make existing storage capacity inadequate.

2.3B The "time-of-day" pumping concept suggests that pumps be operated during periods of off-peak electrical demands — namely, the hours between 10 p.m. and 6 a.m.

2.3C Instruments operate water supply systems by measuring water supply system pressures and water levels in storage tanks. Pumps are automatically started and stopped by controls on the basis of measurements by instruments.

2.3D Three abnormal condtions encountered by operators of water storage facilities include: (1) excessive water demands, such as fire demands, (2) broken or out-of-service pumps, mains or tanks, and (3) stale water creating tastes and odors.

Answers to questions on page 30.

2.3E The main function of a distribution storage reservoir is to take care of daily demands and especially peak demands.

2.3F Operators should know how high the level in a storage tank should be each morning so that the system's demands will be met during the rest of the day.

2.3G Water levels may be controlled in storage reservoirs either manually (by the operator) or by automatic control.

Answers to questions on page 31.

2.3H Depths of water in a storage facility can be measured by the use of floats, electrodes, ultrasonic signals, pressure switches and solid-state electronic sensors.

2.3I Two problems may be encountered when using electrodes to measure water depths. The electrodes may corrode or become difficult to reach for replacement and repair.

2.3J When the pump running light is on, the pump may not be pumping water.

Answers to questions on page 31.

2.3K A pump is primed when the impeller is submerged in water.

2.3L A pump can be primed by use of a (1) special primer pump, (2) priming tank or auxiliary water supply, and (3) removal of air by use of a vacuum pump.

2.3M The electric current and water surge can be reduced when starting a centrifugal pump by starting the pump with the discharge valve closed or throttled.

Answers to questions on page 33.

2.3N Water quality indicators which may help you decide when a water storage tank needs cleaning include: (1) turbidity, (2) color, (3) tastes and odors, and (4) positive bacteriological test results.

2.3O Five possible causes of tastes and odors in a water supply include: (1) high chlorine residual, (2) biological (algal) growths, (3) microorganisms, and (4) dead-ends in mains or tanks.

2.3P Three possible causes of positive coliform test results in a water storage tank include: (1) contaminated distribution system, (2) cross-connection, (3) negative pressure in a water main, and (4) no or improper disinfection of new or repaired wells, reservoirs or mains.

Answers to questions on page 36.

2.4A Preventive maintenance is the repair or adjustment of equipment and facilities which is done before some type of deterioration takes place.

2.4B Corrective maintenance or repair is maintenance which is necessary when a problem already exists.

2.4C The time interval for painting the outside of steel tanks depends on (1) proper surface preparation, (2) a good, durable paint, (3) good workmanship, (4) adequate drying and aging, and (5) proper maintenance through periodic inspection and spot, partial or complete removal of old paint and repainting as necessary.

2.4D The ideal time of year for taking a water storage facility out of service for complete cleaning and inspection is when the water consumption is lowest. For water utilities in warm climates, this time period is from October to April.

2.4E The interior surface of a tank is prepared for repainting by sand blasting.

Answers to questions on page 37.

2.4F Five methods of corrosion control include: (1) a coat of paint, (2) metallic coatings, (3) non-metallic coatings, (4) chemicals for the treatment of water, and (5) electrical control (cathodic protection).

2.4G A corrosion inhibitor is any substance which promotes film formation when added to water.

2.4H The key to a successful cathodic protection program is the replacement of the sacrificial anodes when they have been corroded away. These anodes (sacrificial) should be inspected at least yearly and replaced when necessary.

Answers to questions on page 41.

2.4I The three common types of disinfectants used to disinfect water storage facilities are (1) liquid chlorine (or gas), (2) calcium hypochlorite, and (3) sodium hypochlorite.

2.4J A water storage tank may be disinfected by (1) spraying the interior with a 200 mg/*L* chlorine solution and then filling the tank with water with 3 mg/*L* chlorine residual and allowing the water to remain in the tank for 3 to 6 hours, or (2) apply sufficient chlorine to the water entering the tank to end up with a chlorine residual of 3.0 mg/*L* and hold the water in the tank for 24 hours.

2.4K Chlorine gas is used to disinfect water storage tanks larger than 100,000 gallons while sodium hypochlorite is used to disinfect smaller water storage tanks.

Answers to questions on page 42.

2.4L No, the maintenance of concrete storage facilities is very similar to steel tanks. Operators must inspect concrete tanks for cracks where water could leak out or contaminated water could flow into the storage facility.

2.4M Water level indicators such as floats or electric sensors may be damaged when icing occurs.

2.4N Problems that can be caused by ice buildup on the outside of an elevated reservoir include eroded paint surfaces, increased load on structural supports and a falling ice hazard.

Answers to questions on page 43.

2.5A A booster pump is used to increase the pressure in the mains on the discharge side of the main pumps or to supply water to an elevated storage tank.

2.5B Two points which are critical to the successful operation of a booster pump are the initial installation and the alignment.

2.5C Regulator stations are used to reduce pressure and to maintain an even (low), acceptable pressure downstream from a high pressure system.

2.5D Gages are usually located on the discharge side of a pump. These pressure readings are used to indicate the efficiency of a pump and the loss of water in mains. Gages are also used to indicate water system pressures.

Answers to questions on page 45.

2.6A Records regarding equipment should include the nameplate data, date of installation, start-up data, and any type of service performed on the equipment.

2.7A Safety precautions that should be exercised when working around a water storage facility include:

1. Make sure area around the storage facility is clean and clear of debris,
2. Use care when climbing storage facility ladders and stairways, and
3. When entering a storage facility for inspection, test the atmosphere and make sure you have adequate ventilation.

OBJECTIVE TEST

Chapter 2. STORAGE FACILITIES

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple choice questions.

True-False

1. Hydropneumatic tanks are pressure vessels.
   1. True
   2. False
2. Surge tanks should always be located as close as possible to the activity which creates the water hammer.
   1. True
   2. False
3. The main purpose of a surge tank is to store water.
   1. True
   2. False
4. Stand pipes have a diameter greater than their height.
   1. True
   2. False
5. The best method of applying a coat of paint is by brushing.
   1. True
   2. False
6. If an interior paint is allowed to dry too long, problems with tastes and odors in the water may occur.
   1. True
   2. False
7. Never attempt to start a centrifugal pump until you know that the pump is primed.
   1. True
   2. False
8. Maintenance is a necessary key in the efficient operation of any water system.
   1. True
   2. False
9. Hypochlorite is used to disinfect small water storage tanks.
   1. True
   2. False
10. A coat of paint is the most expensive type of corrosion control.
    1. True
    2. False

Multiple-Choice

11. Tastes and odors in treated water storage facilities can be caused by
    1. Activated carbon.
    2. Algae growths.
    3. High chlorine residuals.
    4. Potassium permanganate.
    5. Silt or clay in suspension.
12. Color in treated water from storage facilities may be caused by
    1. Decay of vegetable matter.
    2. Dissolved gases.
    3. Microscopic organisms.
    4. Phenolic compounds.
    5. Silt or clay in suspension.
13. The ideal time of the year in a warm climate when a water storage facility should be taken out of service for complete cleaning and inspection is generally during the period from
    1. January to June.
    2. July to December.
    3. May to July.
    4. March to November.
    5. October to April.
14. One method of disinfecting the interior of a water storage tank after it has been out of service for inspection is to spray the interior walls with a mg/L chlorine solution.
    1. 10
    2. 50
    3. 100
    4. 200
    5. 500
15. Advantages of water storage facilities include
    1. Demands on source water and facilities are more nearly equalized.
    2. Interior coatings are permanent.
    3. Reserve water supplies are provided.
    4. System flows and pressures are improved and stabilized.
    5. Taste and odor problems are prevented.
16. Inspection of a continuously operating centrifugal pump should include observing and recording
    1. Electrical current demands.
    2. Excessive or abnormal noises.
    3. Leakage from packing glands.
    4. Output flow.
    5. Pump suction and discharge pressure.

17. Valves in a regulator station should be inspected and overhauled at least once every

    1. 6 months.
    2. 1 year.
    3. 2 years.
    4. 3 years.
    5. 5 years.

18. A centrifugal pump may be primed by the use of a(n)

    1. Air gap system.
    2. Auxiliary water supply.
    3. Priming water tank.
    4. Special pump primer.
    5. Vacuum pump.

19. The time interval between paintings of the outside of a steel water tank depends on

    1. Durability of paint.
    2. Proper surface preparation.
    3. Quality of water.
    4. Weather conditions.
    5. Workmanship when paint applied.

20. Water quality problems found in treated water storage facilities include

    1. Color.
    2. Hardness.
    3. Positive coliform test results.
    4. Tastes and odors.
    5. Turbidity.

21. Methods of controlling corrosion in water storage tanks include

    1. Application of metallic coatings.
    2. Cathodic protection.
    3. Chemical treatment of water.
    4. Painting inside surfaces.
    5. Regularly draining and refilling tank.

22. Possible causes of excessive pump vibration or noise include

    1. Foot valve partially clogged.
    2. Inlet of suction pipe insufficiently submerged.
    3. Misalignment.
    4. Operation at very low capacity.
    5. Suction lift too high.

23. Possible causes of a centrifugal pump not delivering water include

    1. Air pocket in suction line.
    2. Discharge valve open.
    3. Foot valve malfunctioning.
    4. Pump not primed.
    5. Suction lift too high.

24. How many gallons of hypochlorite (5 percent available chlorine) have to be added to 150 gallons of water to produce a 200 mg/*L* chlorine solution?

    1. 0.20 gallons
    2. 0.60 gallons
    3. 0.67 gallons
    4. 2.0 gallons
    5. 5.0 gallons

25. Calculate the volume of water in cubic feet in a rectangular water storage tank 30 feet long, 20 feet wide and the water is 8 feet deep.

    1. 600 cu ft
    2. 1,000 cu ft
    3. 3,000 cu ft
    4. 4,800 cu ft
    5. 10,000 cu ft

26. A water storage tank contains 3,000 cubic feet of water. How many gallons of water is in the tank?

    1. 360 gallons
    2. 3,740 gallons
    3. 22,440 gallons
    4. 24,240 gallons
    5. 25,020 gallons

27. How many gallons of water are in a circular water storage tank 25 feet in diameter when the water is 8 feet deep?

    1. 1,175 gallons
    2. 14,092 gallons
    3. 18,790 gallons
    4. 22,020 gallons
    5. 29,360 gallons

28. How many pounds of water are in a tank that contains 300 gallons of water?

    1. 5 lbs
    2. 36 lbs
    3. 40 lbs
    4. 224 lbs
    5. 2,502 lbs

END OF OBJECTIVE TEST

APPENDIX

SURGE IN PIPELINES CARRYING LIQUID

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SURGE IN PIPELINES CARRYING LIQUIDS

INTRODUCTION

Inertia is the tendency of matter to remain in its existing state of motion unless acted upon by outside forces. More energy is required to change steady state motion than to maintain it.

Thus more energy is expended to increase or decrease flowing velocity in a pipeline than is necessary to maintain the liquid's steady state motion. One measure of the energy used to change liquid motion is pressure. If velocity is changed quickly by the application of much energy in a short period of time, the pressure change will be more significant than when the same amount of energy is expended over a longer time period. Thus, the energy applied to change pressure by 100 psi in one second is the same amount of energy as that applied for 10 seconds to change pressure by 10 psi.

BASIC CONCEPT

Any change from steady state conditions creates a temporary variation in pressure or flow called a hydraulic transient. Hydraulic transients are commonly called surge, shock, or water hammer. They are usually caused by opening, closing or regulating valves; or by pumps starting or stopping. Their magnitude is a function of the: (1) change in flowing velocity; (2) liquid density; and (3) sound speed in the liquid and piping system.

These hydraulic transients may range in importance from a slight pressure and/or velocity change, to sufficiently high vacuum or pressure to collapse or burst pipes and fittings or damage pumps.

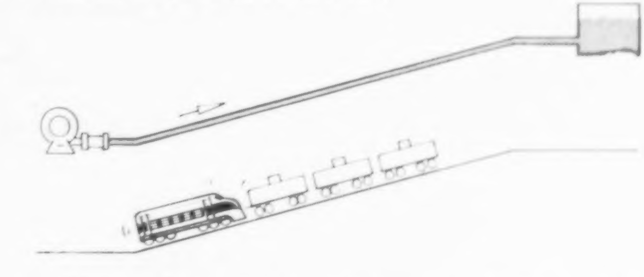
Surge Arrestors are designed to control rapid velocity changes which may cause potentially dangerous pressure excursions.

This is accomplished by using a vessel charged with air or gas and connected to the pipeline carrying the liquid. This vessel has the capability to convert the kinetic energy of the moving liquid into stored potential energy when a liquid overpressure occurs. When a pump stops, the vessel gas expands and "pumps" needed fluid into the line to prevent the formation of vacuum and column separation.

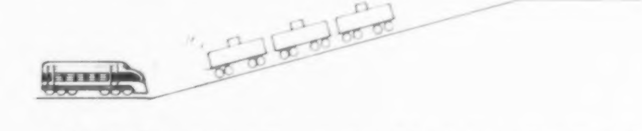
It is this *hydropneumatic* feature which gives the Surge Arrestor its ability to control the *rate* of energy change.

An analogy can be drawn to develop an understanding of hydraulic transients and how the Surge Arrestor controls energy changes.

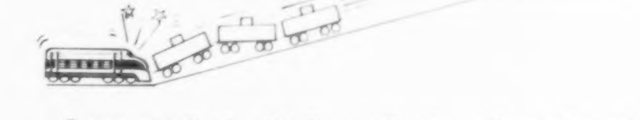
Consider that a railroad locomotive pushing railcars up a grade is similar to a pump pushing a column of liquid through a pipeline to an elevated reservoir.



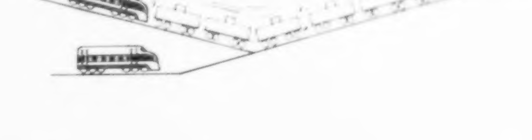
When the locomotive stops, the cars coast until stopped by friction and gravity.



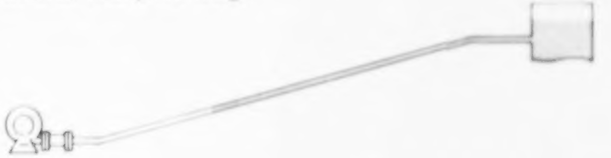
Gravity then causes the cars to roll back down the hill until they crash into the locomotive.



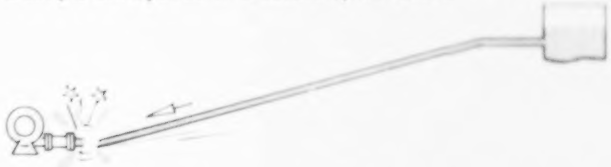
One can easily visualize the results. No crash would result if the railroad had a switch engine to move other cars from a sidetrack to the mainline behind the coasting cars to ease the reverse motion of the railcars back to the stopped locomotive.



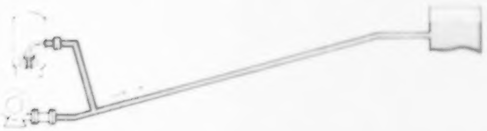
And so it is with the pump-liquid pipeline system. When the pump stops, the liquid flows away from the pump, the liquid column separates and forms a vacuum downstream from the check valve until under the influence of gravity and friction, it stops moving.



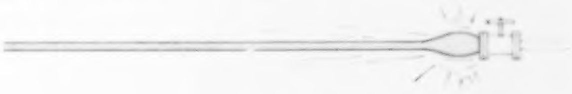
Then gravity causes it to reverse direction until it crashes into the closed check valve. The resulting shock may cause a simple annoyance or a catastrophic failure.



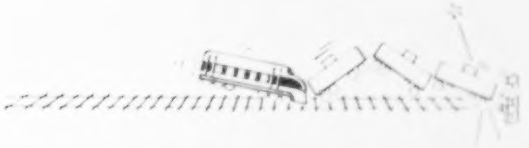
And again no shock would result if the pump-pipeline system is fitted with a hydropneumatic surge arrestor. It would force liquid into the pipeline replacing the pump flow for enough time to prevent liquid column separation and cushions reverse flow until equilibrium is established.



Shock in liquid systems may also be caused by rapid valve movement. This can be reduced by slower regulation of the valve action. Emergency valve requirements as in fire, deluge, and fuel transfer installations may not permit this type of regulation.

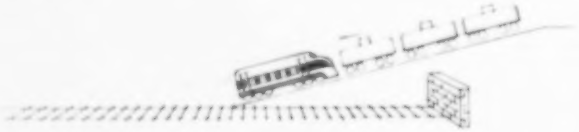


Liquid stopped by a quick closing valve would be like running the train head on into a large solid wall.

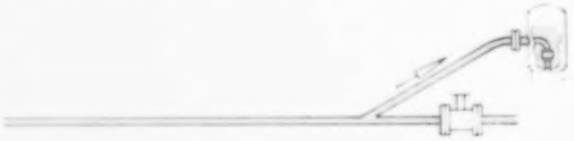


Bringing the train to a gradual halt by braking would parallel controlled (slower) valve closure.

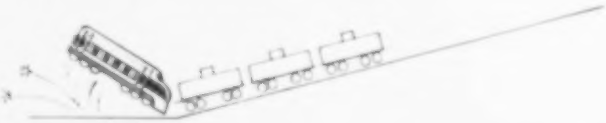
A sidetrack up a hill would safely slow the train to a gradual stop without damage if the obstruction cannot be removed.



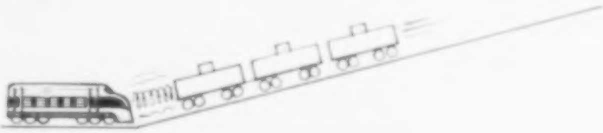
A fast acting valve could not cause damaging shock if a hydropneumatic surge arrestor is mounted up-stream to "sidetrack," slow, and safely stop liquid movement.



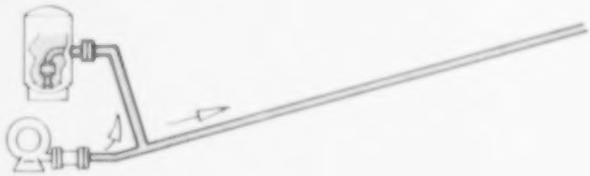
Another place where energy is wasted and has a potential for damage is on startup of pumps. This energy is easy to recognize in the railroad analogy. The locomotive must race its engine and spin its wheels to overcome inertia to get a long train of railcars moving.



If the energy could be averaged by means of a large spring between the locomotive and the train, a smooth start would result.



The high burst of energy required to overcome the inertia of liquid in a pipeline when a pump starts may similarly be averaged by the use of a hydropneumatic surge arrestor on the pump discharge.



HOW TO CONTROL SURGE?

Because surge is a complex problem, many solutions have been attempted. The following list compares some of these solutions.

METHOD	ADVANTAGES	DISADVANTAGES	APPLICATION
None (ignore the problem)	No direct cost to plant; no fit-up problem.	Severe water hammer. Requires that pipe, supports, fittings be extra strong and designed for shock. Costly high pressure design required.	High pressure steel lines.
Surge Control Valve	Easy to fit into plant.	Valve must be exercised regularly to insure operation. Partially drains line. Reverses flow. Requires service and periodic maintenance. Needle valves and close internal tolerances may scale or plug-up. Medium cost.	Transmission lines with smooth gradients and no service turnouts.
Back-spin pump with slow-closing discharge valve	Easy to fit into plant.	Pump and motor must be specially designed. Reverse flow may reach high velocity and cause damage. Not applicable for booster applications. Medium cost.	Transmission lines with smooth gradients and no service turnouts.
Flywheels	Good for large, short lines.	Requires reduced voltage starters. Keyways, couplings, bearings hard to maintain. Special pump and motor shaft requirements. High cost.	Transmission lines with smooth gradients and no service turnouts.
One way surge tanks or standpipes	Open tank not a pressure vessel. Controlled upsurge and down surge. Predictable performance.	Requires drawdown to tank level. Requires valve service. May be difficult to fit into plant. Medium cost.	Transmission lines with smooth gradients and no service turnouts.
Combination hydropneumatic tank with vacuum valve	May be buried. Reduces volume requirements for low lift-applications. Good for force main applications. Predictable performance.	Requires drawdown to tank elevation. May be difficult to fit into plant. Valve must be serviced. Medium cost.	Transmission lines with smooth gradients and no service turnouts.
Hydropneumatic surge arrestor	Minimum service. Controlled upsurge and downsurge. Predictable performance. Fail safe. Good for booster applications. Single pump check is only valve required. Permits use of thin-wall piping.	May be difficult to fit into plant. Becomes large for low-lift applications. Medium cost.	All including irregular profile and service turnouts.

CHAPTER 3

DISTRIBUTION SYSTEM FACILITIES

by

Sam Kalichman

and

Nick Nichols

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OBJECTIVES

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

Following completion of Chapter 3, you should be able to:

1. Explain the purpose of a water distribution system,
2. Describe the importance of hydraulics in the performance of a distribution system,
3. Explain the purpose of distribution system storage and pumping facilities,
4. Identify various types of pipes and joints,
5. Properly and safely install pipe,
6. Identify and test various types of meters,
7. Identify the various types of backflow prevention devices, and
8. Determine the need for and install backflow prevention devices.

GLOSSARY

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

APPURTENANCE (uh-PURR-ten-nans) APPURTENANCE

Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

BACK PRESSURE BACK PRESSURE

A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

BACKFLOW BACKFLOW

A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than the intended source. Also see BACKSIPHONAGE.

BACKSIPHONAGE BACKSIPHONAGE

A form of backflow caused by a negative or below atmospheric pressure within a water system. Also see BACKFLOW.

C FACTOR C FACTOR

A value or factor used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between two pressure gages, and the friction or energy loss of the water between the gages.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75\ (\text{Diameter, ft})^{2.63}\ (\text{Slope})^{0.54}}$$

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, or pitting of steel and iron surfaces in contact with water or soil.

CORPORATION STOP CORPORATION STOP

A water service shutoff valve located at a street water main. This valve cannot be operated from the ground surface because it is buried and there is no valve box. Also called a *CORPORATION COCK.*

CORROSION CORROSION

The gradual decomposition or destruction of a material by chemical action, often due to an electrochemical reaction. Corrosion may be caused by (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, or (3) differential-concentration cells. Corrosion starts at the surface of a material and moves inward.

CROSS-CONNECTION CROSS-CONNECTION

A connection between drinking (potable) water and an unapproved water supply. For example if you have a pump moving non-potable water and hook into the drinking water system to supply water for the pump seal, a cross-connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

CURB STOP CURB STOP

A water service shutoff valve located in a water service pipe near the curb and between the water main and the building. This valve is usually operated by a wrench or valve key and is used to start or stop flows in the water service line to a building. Also called a *CURB COCK.*

DYNAMIC PRESSURE DYNAMIC PRESSURE

When a pump is operating, the vertical distance (in feet) from a reference point (such as a pump centerline) to the hydraulic grade line is the dynamic head. Also see TOTAL DYNAMIC HEAD, STATIC HEAD, STATIC PRESSURE, and ENERGY GRADE LINE.

Dynamic Pressure, psi = (Dynamic Head, ft)(0.433 psi/ft)

ELECTROLYSIS (ee-leck-TRAWL-uh-sis) ELECTROLYSIS

The decomposition of material by an electric current.

ENERGY GRADE LINE (EGL) ENERGY GRADE LINE (EGL)

A line that represents the elevation of energy head of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line (gradient) a distance equal to the velocity head ($V^2/2g$) of the water flowing at each section or point along the pipe or channel. Also see HYDRAULIC GRADE LINE

[SEE DRAWING ON PAGE 61]

FRICTION LOSSES FRICTION LOSSES

The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses. Also see HEAD LOSS.

GALVANIZE GALVANIZE

To coat a metal (especially iron or steel) with zinc. Galvanization is the process of coating a metal with zinc.

GRADE GRADE

(1) The elevation of the invert (lowest point) of the bottom of a pipeline, canal, culvert or similar conduit.

(2) The inclination or slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5 percent grade would be a drop of one-half foot per hundred feet of pipe.

HEAD LOSS HEAD LOSS

The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or restrictions caused by fittings. Water flowing in a pipe loses head, pressure or energy as a result of friction losses. Also see FRICTION LOSSES.

HIGH-LINE JUMPERS HIGH-LINE JUMPERS

Pipes or hoses connected to fire hydrants and laid on top of the ground to provide emergency water service for an isolated portion of a distribution system.

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. Also see ENERGY GRADE LINE.

[SEE DRAWING ON PAGE 61]

INVERT (IN-vert) INVERT

The lowest point of the channel inside a pipe, conduit, or canal.

MIL MIL

A unit of length equal to 0.001 of an inch. The diameter of wires and tubing is measured in mils, as is the thickness of plastic sheeting.

POTABLE WATER (POE-tuh-bull) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

PRESTRESSED PRESTRESSED

A prestressed pipe has been reinforced with wire strands (which are under tension) to give the pipe an active resistance to loads or pressures on it.

PRESSURE HEAD PRESSURE HEAD

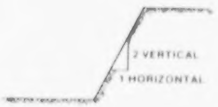
The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

SERVICE PIPE SERVICE PIPE

The pipeline extending from the water main to the building served or to the consumer's system.

SLOPE SLOPE

The slope or inclination of a trench bottom or a trench side wall is the ratio of the vertical distance to the horizontal distance or "rise over run." Also see GRADE (2).



2:1 SLOPE

SLURRY (SLUR-e) SLURRY

A water mixture or suspension of insoluble (not dissolved) matter; a thin watery mud or any substance resembling it (such as a grit slurry or a lime slurry).

SPOIL SPOIL

Excavated material such as soil from the trench of a water main.

SPRING LINE SPRING LINE

Theoretical center of a pipeline. Also, the guideline for laying a course of bricks.

STATIC HEAD STATIC HEAD

When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. (The static pressure in psi is the static head in feet times 0.433 psi/ft.) Also see DYNAMIC PRESSURE and STATIC PRESSURE.

STATIC PRESSURE STATIC PRESSURE

When water is not moving, the vertical distance (in feet) from a specific point to the water is the static head. The static pressure in psi is the static head in feet times 0.433 psi/ft. Also see DYNAMIC PRESSURE and STATIC HEAD.

SURGE CHAMBER SURGE CHAMBER

A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.

TAILGATE SAFETY MEETING TAILGATE SAFETY MEETING

The term *TAILGATE* comes from safety meetings regularly held by the construction industry around the tailgate of a truck.

THRUST BLOCK THRUST BLOCK

A mass of concrete or similar material appropriately placed around a pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.

TOTAL DYNAMIC HEAD (TDH) TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TUBERCULATION (too-BURR-que-LAY-shun) TUBERCULATION

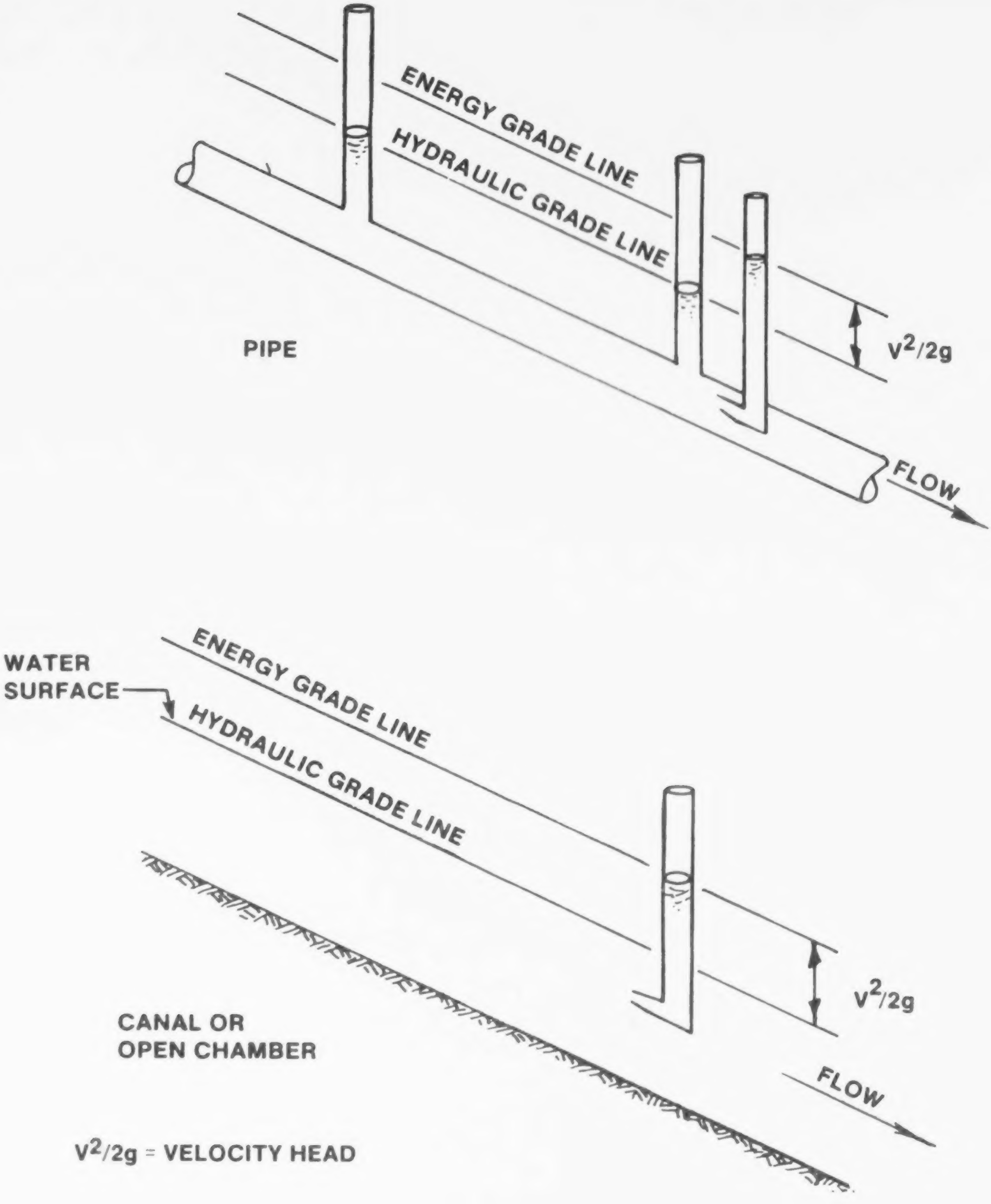
The development or formation of small mounds of corrosion products (rust) on the inside of iron pipe. These mounds (tubercules) increase the roughness of the inside of the pipe thus increasing resistance to water flow (decreases the C Factor).

VELOCITY HEAD VELOCITY HEAD

The energy in flowing water as determined by a vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.


ENERGY GRADE LINE
HYDRAULIC GRADE LINE
PIPE
$V^2/2g$
FLOW
WATER SURFACE
ENERGY GRADE LINE
HYDRAULIC GRADE LINE
CANAL OR OPEN CHAMBER
$V^2/2g$
FLOW
$V^2/2g$ = VELOCITY HEAD

ENERGY GRADE LINE and HYDRAULIC GRADE LINE

CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 1 of 5 Lessons)

3.0 PURPOSE OF DISTRIBUTION SYSTEMS

Water distribution typically consist of pipes, storage facilities, pumping stations, valves, fire hydrants, meters, and other *APURTENANCES*[1] (Figure 3.1). Together, they make up what can be considered a single operating unit working to achieve its intended purpose. That purpose is to deliver adequate quantities of water at sufficient pressures at all times under continually changing conditions while at the same time protecting water quality. Two major elements combine to accomplish this purpose. The first deals with the physical features of the system and relates to its ability to withstand the stresses imposed upon it, to protect the quality of the water it carries, and to deliver the supply in sufficient quantity through adequately-sized facilities. The second element is the operation and maintenance of the system in a manner that preserves its integrity and the quality of the water it delivers. Of special importance is the maintenance of a *CONTINUOUS POSITIVE WATER PRESSURE* in the system under all conditions so as to protect the distribution system from the entrance of toxic and other undesirable substances. To properly understand and operate a distribution system, the operator must be thoroughly knowledgeable about both its physical and hydraulic characteristics. This chapter deals with the physical and hydraulic characteristics of a distribution system. The next chapter, Chapter 7, discusses the water quality aspects and the following chapter outlines the procedures to operate and maintain a distribution system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.0A List the major parts of a water distribution system.

3.0B Why must a continuous positive water pressure be maintained in the distribution system at all times?

3.1 DISTRIBUTION SYSTEM HYDRAULICS

The major hydraulic concerns of a water distribution system are (1) will water flow and (2) in what direction? Also available pressures are of prime concern. Different agencies may use different values for target or desired minimum pressures. Generally, water should be delivered with a working minimum pressure of 35 pounds per square inch (psi) (241 kiloPascal or 2.5 kilograms per square centimeter) to all points in a distribution system. Twenty psi (138 kPa or 1.4 kg/sq cm) at a delivery point would be the absolute minimum. Excessive pressures (greater than 100 psi, 690 kPa or 7 kg/sq cm) will damage the customer's facilities and plumbing fixtures.

Accomplishing these hydraulic goals sometimes becomes very complex when a distribution system serves consumers living on high hills or in deep valleys. Another factor that must be considered is the fact that water flowing in a pipe or conduit will lose pressure due to pipe *FRICTION LOSS*.[2] Water pressure problems created by hills and valleys are a lesser concern than friction losses because pressure problems due to elevation can be anticipated and corrected when the distribution system is designed. However, the loss of pressure due to friction in a pipeline is not constant, being determined by the roughness of the interior of the pipe creating turbulence proportional to the velocity of water flowing in the pipe. This velocity is constantly changing with demand while pipe roughness can gradually increase over a period of time.

All pipes have a roughness which resists water flow and causes a drop in pressure under dynamic (flowing) conditions. The roughness is indicated by a factor called a *C FACTOR*.[3] The higher the C Factor, the smoother the inside of the pipe. Some pipe roughness is natural (due to the material used in the pipe construction); it will increase with deposits along the pipeline or pipe deterioration (corrosion).

To understand the hydraulics of a water supply system, there are several other technical terms you will need to master. Refer to the drawings on the next few pages if you have trouble picturing these concepts.

To begin with, imagine you are looking at one of the distribution pipes in a water supply system. If you were to drill a small hole in the top of the pipe and attach a vertical pipe to the hole, the water in the pipe would rise in the tube a

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[1] *Appurtenance (uh-PURR-ten-nans). Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.*

[2] *Friction Losses. The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses.*

[3] *C Factor. A value or factor used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between two pressure gages, and the friction or energy loss of water between the gages.*

Slope = (Energy Loss)/Distance.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75(\text{Diameter, ft})^{2.63}\,(\text{Slope})^{0.54}}$$

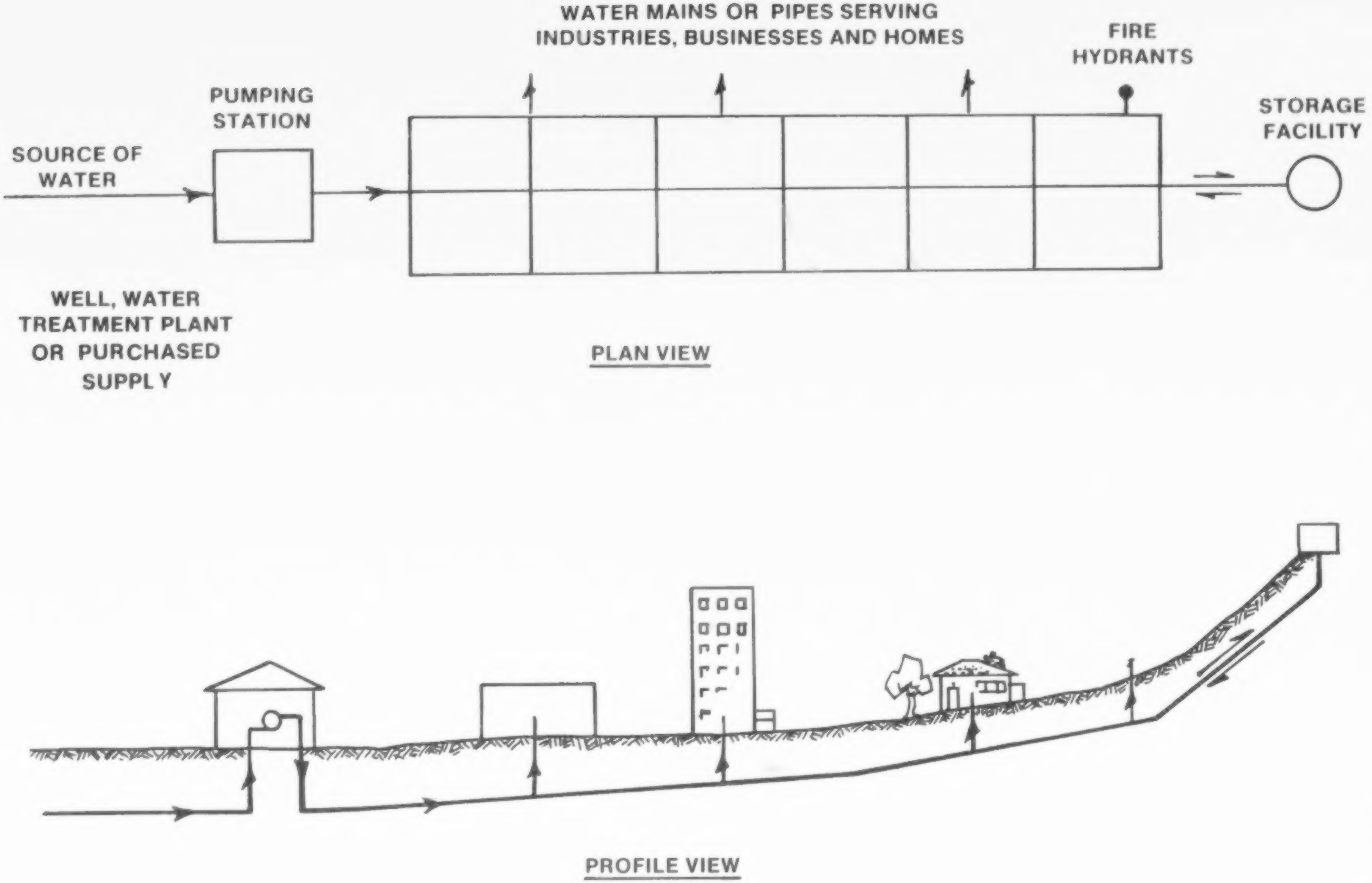
WATER MAINS OR PIPES SERVING
INDUSTRIES, BUSINESSES AND HOMES
FIRE
HYDRANTS
PUMPING
STATION
STORAGE
FACILITY
SOURCE OF
WATER
WELL, WATER
TREATMENT PLANT
OR PURCHASED
SUPPLY
PLAN VIEW
PROFILE VIEW

Fig. 3.1 Typical water distribution system facilities

77

78

distance equal to the *PRESSURE HEAD.*[4] If you drilled several holes along the top of the pipe and inserted vertical tubes in each hole, the line connecting the top of the water in each tube would form the *HYDRAULIC GRADE LINE*[5] (also called the hydraulic gradient). The hydraulic grade line always slopes downward in the direction of flow in a pipe, regardless of the actual *SLOPE*[6] of the pipe (Figure 3.2).

When water changes its direction of flow in a pipe, the direction of the slope of the hydraulic grade line will also change. For example, if water is flowing into an elevated water storage reservoir, the hydraulic grade line will slope downward towards the reservoir. When water is flowing out of a reservoir during periods of high demand, the hydraulic grade line will slope downward, away from the reservoir (Figure 3.3).

A major fire, leak or other unanticipated high demand for water might draw the hydraulic grade line down to a point that a negative pressure (vacuum) is created at some service connections (Figure 3.4). This negative pressure could cause *BACKFLOW*[7] from a nonpotable source of water and contaminate the distribution system.

The hydraulic grade line is also affected by obstructions in the pipe line such as throttled valves (Figure 3.5). If pipe diameters are too small and/or flows are too great, the hydraulic grade line can drop very quickly and result in pressures that are too low. Remember, the pressures in a pipe are represented by the distance or size of the pressure head (the distance from the pressure gage to the hydraulic grade line). One way to evaluate your distribution system is take pressure readings at various locations (such as fire hydrants) along a water main. By plotting the elevations of the hydraulic grade line on a profile drawing of the water main, you can locate obstructions (such as throttled or stuck valves) and other flow-limiting factors.

Other factors of hydraulic concern are thrust and *WATER HAMMER.*[8] Water flowing in a pipe exerts thrust at any point where the layout of the system either changes the direction of the flow, increases the velocity, or decreases or stops the flow. At these points, the pipes and fittings must be anchored and kept from moving or pulling apart by the use of *THRUST BLOCKS*[9] (Figure 3.6). Thrust blocks (or "kickers") distribute the thrust on the soil in such a manner that the thrust does not exceed the carrying capacity of the soil. Improperly installed thrust blocks can cause considerable damage to the pipe and fitting. Thrust blocks are not required on pipe where the joints are fixed (due to a mechanical anchorage such as welding) and cannot be pulled apart.

Water hammer is caused by surges in the pipeline resulting from the rapid increase or decrease in water flow. This usually results from the turning on or off of pumps or by operating valves too rapidly. Water hammer exerts tremendous forces on the system and can be highly destructive. *SURGE CHAMBERS*[10] (Fiture 3.7) are sometimes used to control water hammer. For a detailed description of surges and methods of controlling them, see Chapter 2, "Storage Facilities," Appendix, "Surge in Pipelines Carrying Liquids." Operators, firemen and anyone else authorized to open and close valves or start and stop pumps, must be trained to slowly open and close valves. Large pumps should not be placed on line and started or stopped quickly.

FORMULAS

Frequently we determine the pressure in a main or at a fire hydrant by reading a pressure gage in psi (pounds per square inch). To convert a pressure reading in psi to a pressure head in feet, use the conversion factor 2.31 ft per psi. This means that a column of water 2.31 feet high would exert a pressure of one pound over one square inch.

$$\text{Pressure Head, ft} = (\text{Pressure, psi})(2.31\ \text{ft/psi})$$

If we were given the pressure head in feet from a pressure gage, we could rearrange the above formula to determine the pressure in psi.

$$\text{Pressure, psi} = \frac{\text{Pressure Head, ft}}{2.31\ \text{ft/psi}}$$

or

$$\text{Pressure, psi} = (\text{Pressure Head, ft})(0.433\ \text{psi/ft})$$

We obtained 0.433 psi/ft by solving for 1/2.31 ft/psi = 0.433 psi/ft. This term says that a column of water one foot high will exert a pressure of 0.433 pounds over one square inch.

EXAMPLE 1

A pressure gage on a fire hydrant reads 40 psi. What is the pressure head in feet at the fire hydrant?

Known	**Unknown**
Pressure, psi = 40 psi	Pressure Head, ft

Calculate pressure head in feet.

$$\begin{aligned}\text{Pressure Head, ft} &= (\text{Pressure, psi})(2.31\ \text{ft/psi})\\ &= (40\ \text{psi})(2.31\ \text{ft/psi})\\ &= (92.4\ \text{ft})\end{aligned}$$

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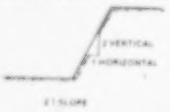
[4] *Pressure Head. The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.*

[5] *Hydraulic Grade Line (HGL). The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe.*

[6] *Slope. The slope or inclination of a trench bottom or a trench side wall is the ratio of the vertical distance to the horizontal distance or "rise over run."*

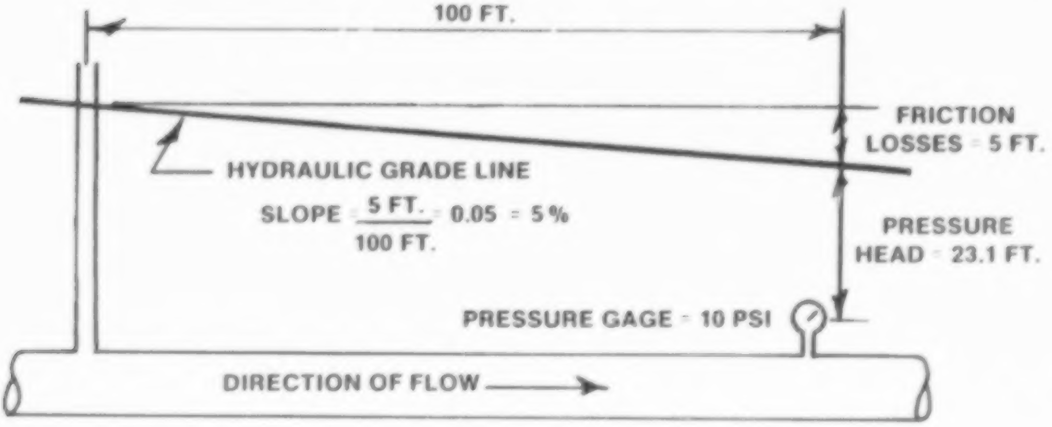


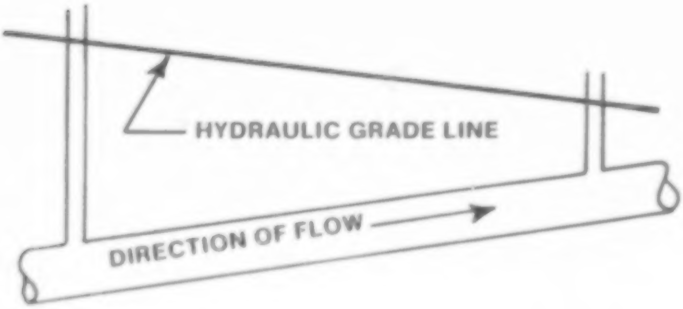
[7] *Backflow. A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than the intended source.*

[8] *Water Hammer. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.*

[9] *Thrust Block. A mass of concrete or similar material appropriately placed around a pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.*

[10] *Surge Chamber. A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.*


100 FT.
FRICTION LOSSES = 5 FT.
HYDRAULIC GRADE LINE
SLOPE = 5 FT. / 100 FT. = 0.05 = 5%
PRESSURE HEAD = 23.1 FT.
PRESSURE GAGE = 10 PSI
DIRECTION OF FLOW


HYDRAULIC GRADE LINE
DIRECTION OF FLOW

NOTE: The hydraulic grade line *ALWAYS* slopes downward in the direction of flow

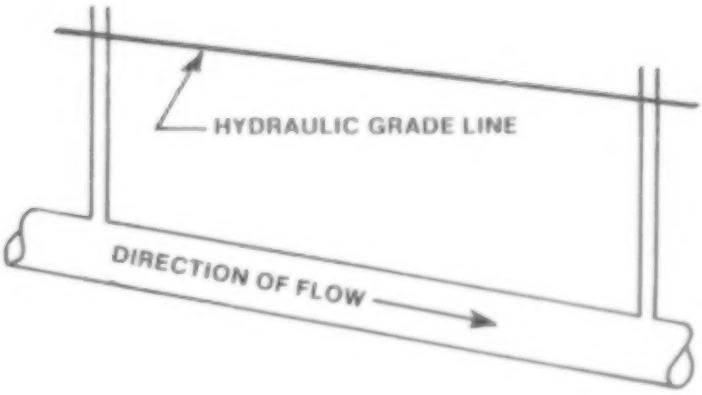
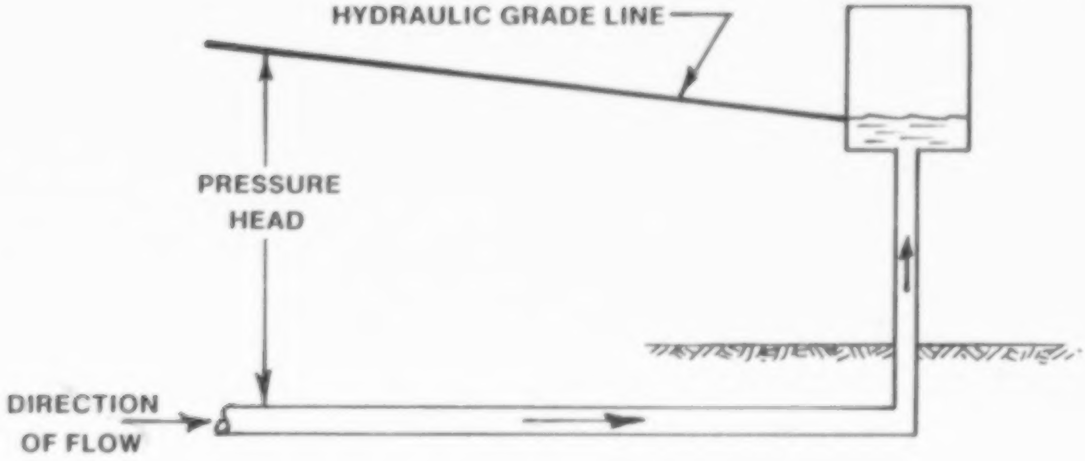
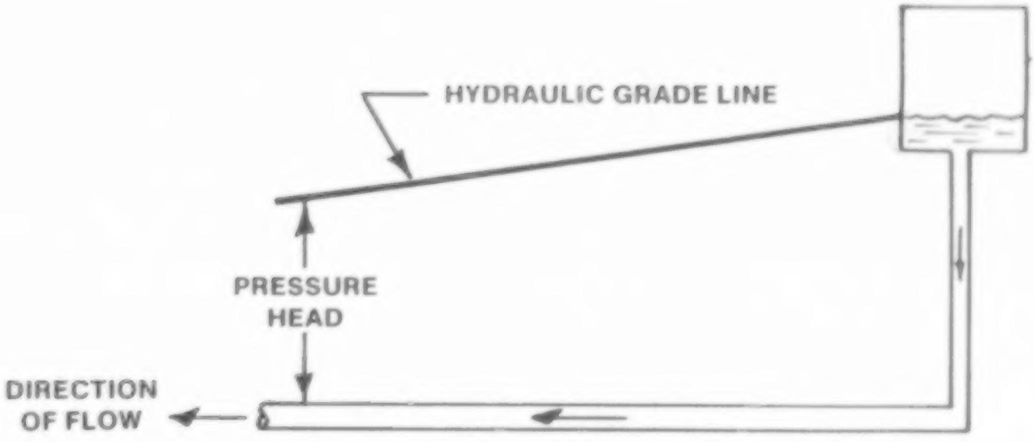

HYDRAULIC GRADE LINE
DIRECTION OF FLOW

Fig. 3.2 Hydraulic grade lines

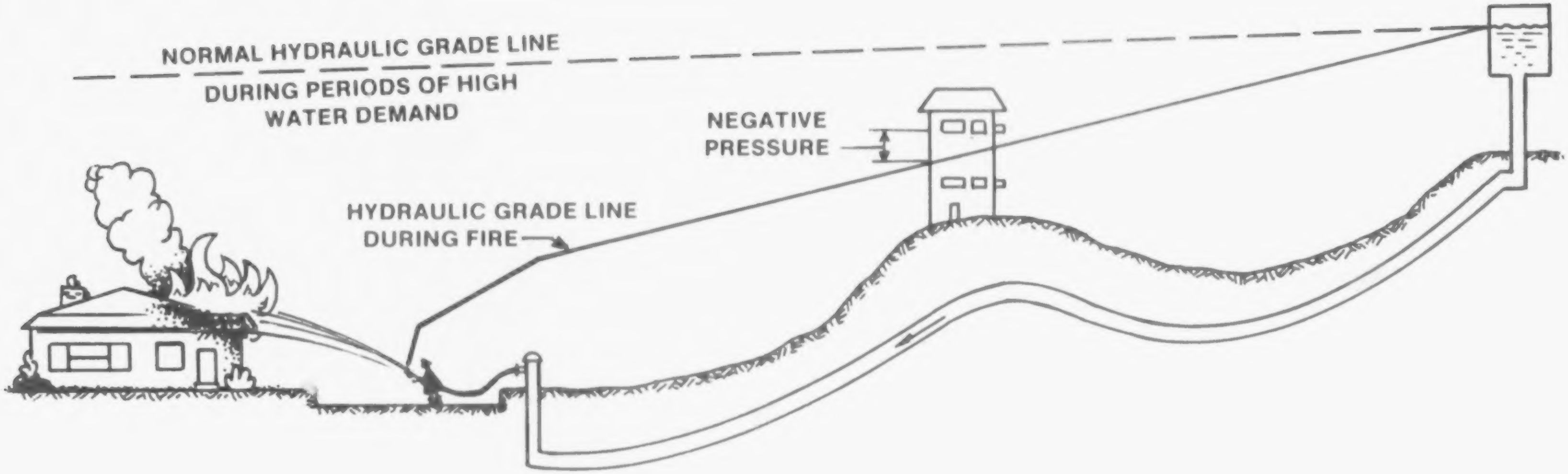

HYDRAULIC GRADE LINE
PRESSURE HEAD
DIRECTION OF FLOW

STORAGE RESERVOIR FILLING


HYDRAULIC GRADE LINE
PRESSURE HEAD
DIRECTION OF FLOW

STORAGE RESERVOIR EMPTYING

Fig. 3.3 Storage reservoir hydraulic grade lines


NORMAL HYDRAULIC GRADE LINE
DURING PERIODS OF HIGH
WATER DEMAND
NEGATIVE
PRESSURE
HYDRAULIC GRADE LINE
DURING FIRE

NOTE: Any fixture or faucet above the hydraulic grade line will be exposed to a negative pressure

Fig. 3.4 Negative pressure

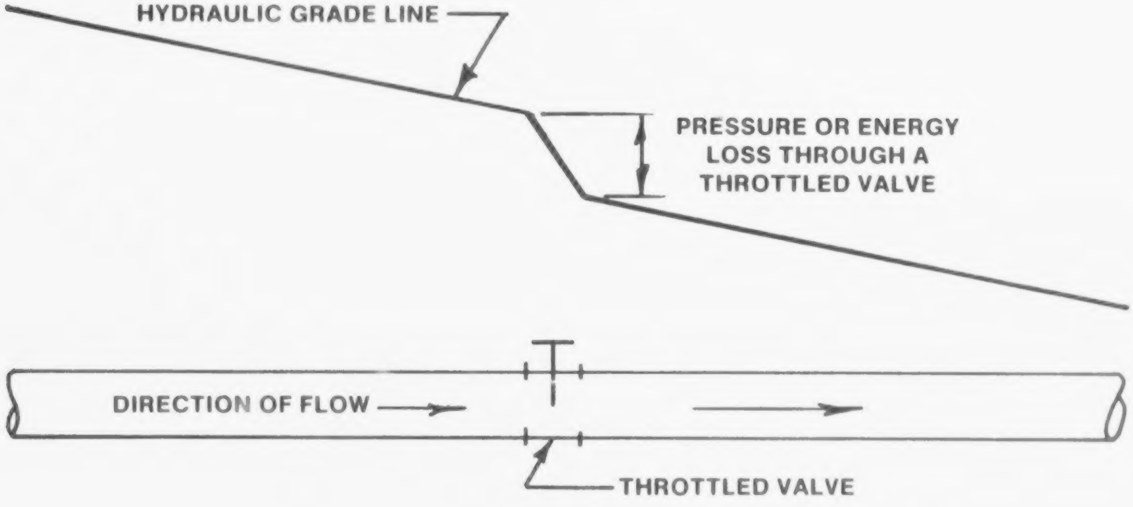
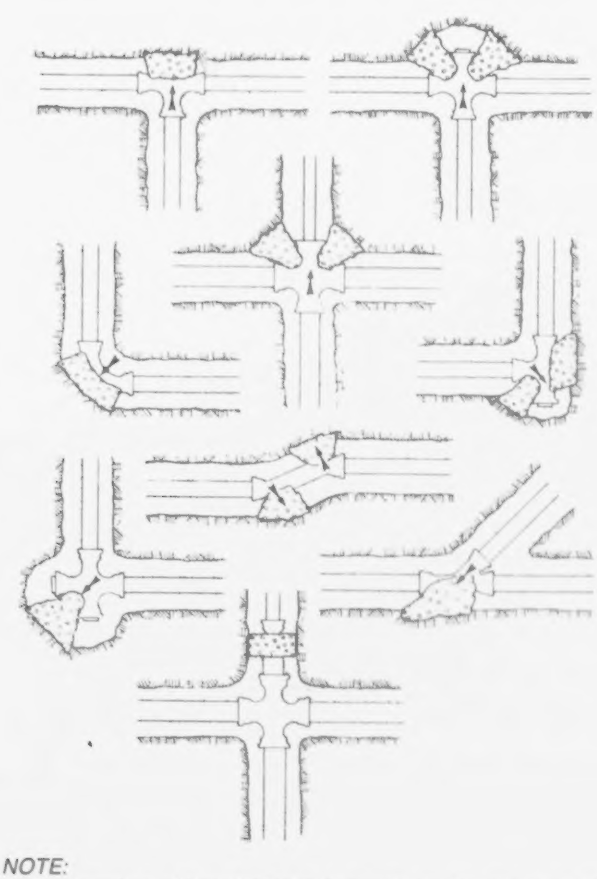

HYDRAULIC GRADE LINE
PRESSURE OR ENERGY LOSS THROUGH A THROTTLED VALVE
DIRECTION OF FLOW
THROTTLED VALVE

Fig 3.5 Throttled valve lowering hydraulic grade line



NOTE:
1. The location of thrust blocks depends on the direction of thrust and type of fitting as shown above.
2. Thrust blocks are not required if the ends of pipe are held tightly by mechanical anchorage such as a weld.

Fig. 3.6 Location of thrust blocks

(Permission of Johns-Manville Corporation, a Subsidiary of Manville Corporation)

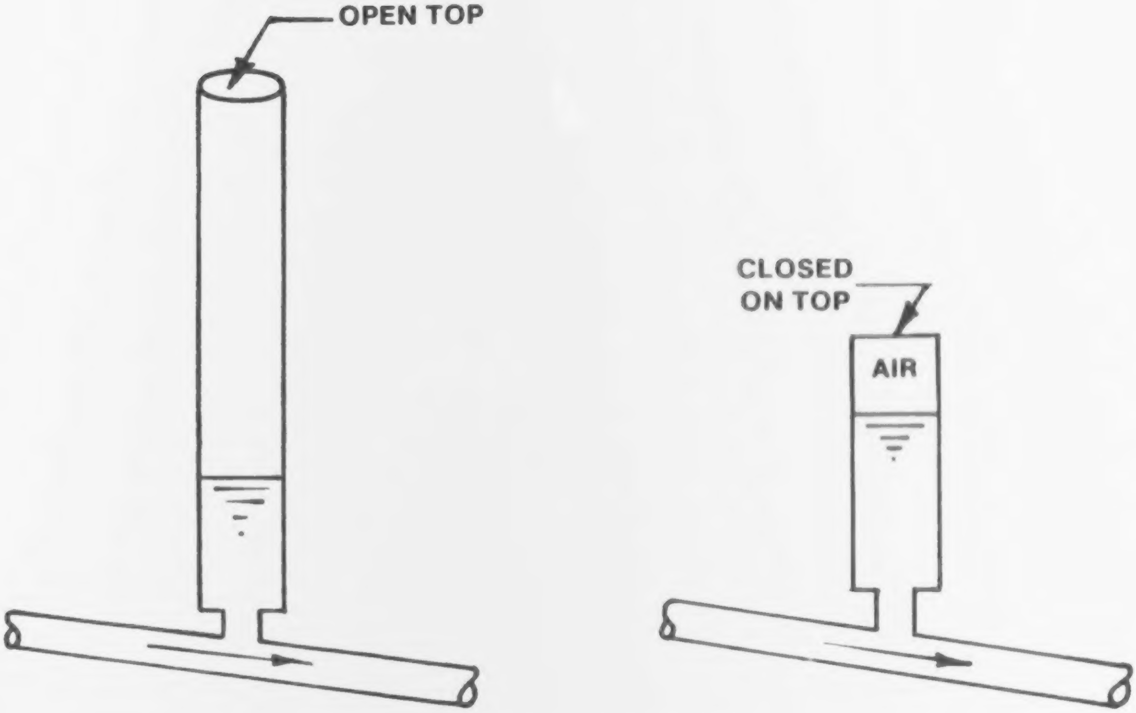


Fig. 3.7 Types of surge chambers

EXAMPLE 2

A pressure gage on a fire hydrant reads 80 feet of pressure head. What is the pressure in psi? *NOTE:* Pressure gages may read in psi and/or feet of head.

Known	Unknown
Pressure Head, ft = 80 ft	Pressure, psi

Calculate the pressure in pounds per square inch (psi).

$$\text{Pressure, psi} = \frac{\text{Pressure Head, ft}}{2.31 \text{ ft/psi}}$$

$$= \frac{80 \text{ ft}}{2.31 \text{ ft/psi}}$$

$$= 34.6 \text{ psi}$$

or

$$\text{Pressure, psi} = (\text{Pressure Head, ft})(0.433 \text{ psi/ft})$$

$$= (80 \text{ ft})(0.433 \text{ psi/ft})$$

$$= 34.6 \text{ psi}$$

EXAMPLE 3 (ADVANCED PROBLEM)

On page 62 the formula appeared showing how to calculate the C Factor. If your calculator can calculate exponents, you can work this problem. A 24-inch diameter water main is carrying a flow of 3000 GPM. Pressure gages installed 1000 feet apart on the main indicate that the elevation of the pressure head at the upstream pressure gage is 101 feet and 100 feet at the downstream pressure gage. Calculate the C Factor for this pipe.

	Known	Unknown
Flow, GPM	= 3000 GPM	C Factor
Diameter, in	= 24 in	
Diameter, ft	= 2 ft	
Distance, ft	= 1000 ft	
Energy Loss, ft	= 101 ft - 100 ft	
	= 1 ft	

1. Calculate the slope.

$$\text{Slope} = \frac{\text{Energy Loss, ft}}{\text{Distance, ft}}$$

$$= \frac{1 \text{ ft}}{1000 \text{ ft}}$$

$$= 0.001 \text{ ft/ft}$$

2. Calculate the C Factor.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75(\text{Diameter, ft})^{2.63}(\text{Slope})^{0.54}}$$

$$= \frac{3000 \text{ GPM}}{193.75(2.0 \text{ ft})^{2.63}(0.001)^{0.54}}$$

$$= \frac{3000}{(193.75)(6.19)(0.02399)}$$

$$= 104$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

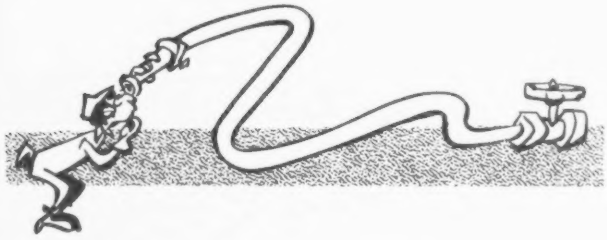
3.1A What problems may be created by excessive pressures in a distribution system?

3.1B What causes friction losses in pipes?

3.1C What conditions might cause thrust in a pipe?

3.1D Water hammer can be caused by what actions?

3.1E During a distribution system pressure test, a pressure gage attached to a faucet in a home read 30 psi. What is the pressure head in feet?



3.2 PERFORMANCE CONSIDERATIONS

Distribution systems and their components should be capable of carrying the required flow at the desired pressures to prevent the introduction of foreign substances and to minimize reactions between the water and parts of the system. Sufficient water must be available from the water sources and distribution reservoirs to supply adequately, dependably, and safely the total requirements of all users under maximum demand conditions.

Distribution system performance considerations include:

1. Demands for water throughout the entire system;
2. Fire fighting water demands;
3. Elevation differences throughout the service area and the *STATIC HEAD*[11] conditions;
4. The most appropriate pipe for the system conditions;
5. Types of soils, depth to rock, groundwater, and frost levels;
6. Quality of the water supply which may affect the type of materials used;
7. Water volumes and pressures needed to minimize the effects of fires, earthquakes, floods, and sabotage;
8. Protection against unauthorized entry and vandalism;
9. Protection against the adverse effects of freezing weather; and
10. Potential service interruptions resulting from power supply, equipment, or structural failures.

The hydraulic adequacy of a distribution system is determined by the pressures that exist at various points in the system under the conditions of operation. While pressures must be high enough to serve the consumers and fire demand, excessive pressures will increase pump energy costs and may have adverse effects on some of the consumers' water-using devices.

Water should be delivered at a minimum desirable pressure of 35 psi (241 kPa or 2.5 kg/sq cm). An absolute minimum pressure is 20 psi (138 kPa or 1.4 kg/sq cm) to all points of the distribution system, and a maximum pressure is 100 psi (690 kPa or 7.0 kg/sq cm).[12] This recommended pressure range insures sufficient pressure for normal use without risk of damage by excessive pressures to water heaters and other plumbing fixtures. In commercial districts, pressures of 75 psi (517 kPa or 5.25 kg/sq cm) and higher are desirable. If excessively high pressures (greater than 100 psi, 690 kPa or 7.0 kg/sq cm) cannot be avoided, pressure-reducing valves may be used (Figure 3.8).

The ideal system would rely completely on gravity to bring water from its source to the consumer at the desired pressures. In most systems, however, some pumping is required. Usually topography (hills and valleys) is such that water must be lifted to distribution reservoirs and elevated tanks. Also, booster pumps are often installed directly on mains to increase the available system pressures.

Pipes should be sufficiently large to carry the maximum quantity of water required at acceptable velocities. Too great a velocity can cause pressure drops and water hammer. Velocities of two to four feet per second (0.6 to 1.2 m/sec) at maximum flows are common and establish the size of water mains to be used. The minimum diameter of pipe commonly installed today is six inches (150 mm). Four-inch (100 mm) pipe should be the absolute minimum size used. Any pipe with a hydrant on the line must be at least six inches (150 mm) in diameter.

Avoid dead-end water mains (Figure 3.9) to prevent the development of tastes and odors. Any dead-end mains exceeding 1,000 feet (100 m) in length should be constructed of pipe at least six inches (150 mm) in diameter. For a dead end 2,000 feet (600 m) in length, the pipes should exceed eight inches (200 mm). A hydrant, flushing valve or blowoff is needed at the end of each dead-end water main for periodic flushing of the line.

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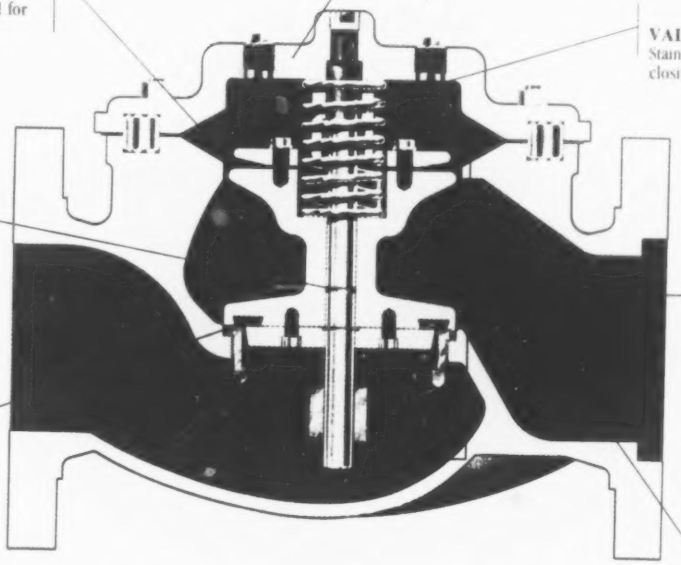
[11] *Static Head. When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. The static pressure in psi is the static head in feet times 0.433 psi/ft.*

[12] *Maximum and minimum pressures vary from place to place and agency to agency. For example, some agencies have a minimum of 40 psi and a maximum of 80 psi.*



DIAPHRAGM
Separates upper chamber operating pressure from low chamber line pressure Buna-N diaphragm standard; Viton available if required; all Nylon reinforced for high strength and long life

BONNET
Four tapped ports for pilot piping Center port for valve position indicator or valve actuated switches Primed and painted like body

VALVE SPRING
Stainless steel spring aids in closing the valve

O-RING
Creates a static seal No packing glands required, therefore breakaway friction is eliminated and valve will operate even at extremely low pressures

DIAPHRAGM ASSEMBLY
The only moving part of the Model 65 valve Ductile iron spool, seat retainer, diaphragm plate Guided top and bottom by bronze or Teflon bushings

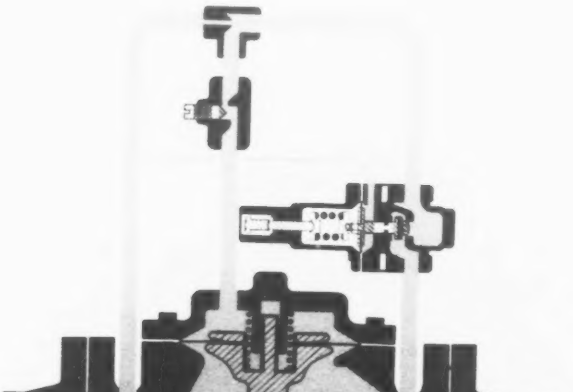
VALVE SEAT
Buna-N or Viton compensates for wear on seating surface and maintains a drip-tight seal over extended service life

BODY
Globe pattern 1-1/4 — 12"; 250 lb iron, 150 & 300 lb steel, 150 lb aluminum Screwed ends 1-1/4 — 3" globe & angle Iron & steel bodies epoxy primed inside and out with baked enamel exterior Four tapped ports for pilot piping

NOTE:
Basic valve can be used as a pressure, relief, altitude control or pressure reducing valve depending on type of "brains" piped to valve.

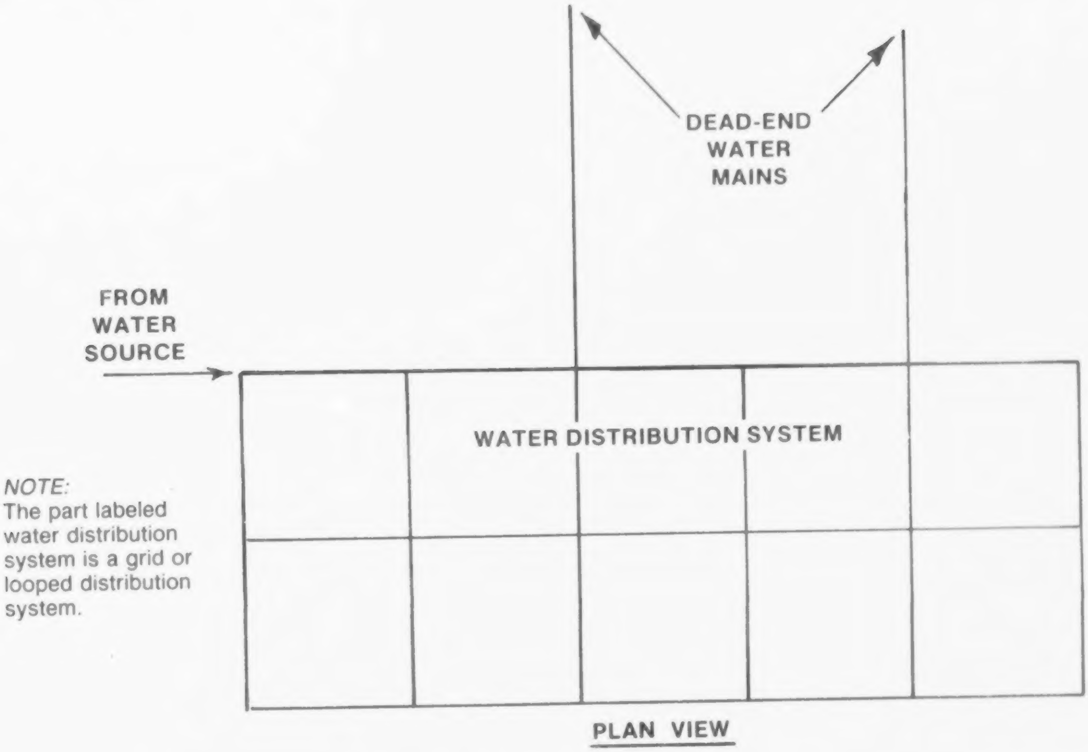
SEAT RING
Bronze or stainless steel ring is replaceable and provides a lower guide for the stainless steel valve stem

BASIC VALVE



(Permission of OCV Control Valves)

Fig 3.8 Pressure reducing valve
(Permission of OCV Control Valves)



NOTE:
The part labeled water distribution system is a grid or looped distribution system.

Fig. 3.9 Dead-end water mains (at top)

The valve layout in a distribution system is very important. In general, valves on water mains of 12 inches (300 mm) in diameter and smaller should be located so that water main lengths of not more than 1,000 feet (300 m) can be isolated by valve closures. Fire hydrants should not be more than 500 feet (150 m) apart to avoid excessive *HEAD LOSS*[13] in fire hoses when fighting a fire.

Distribution reservoir capacity should be sufficient to meet the equalizing or operating storage demands, fire reserve, and emergency reserve. In pumped water supply systems, the cost of storage is balanced against cost of pumping. In all water supply systems, the cost of storage must be balanced against the cost of supply lines, increased fire protection and more uniform pressures in the distribution system. Storage provides savings in energy consumption because tanks can be filled during periods of low water and energy demand, and the stored water used to meet peak water demands. Storage capacity of this type will eliminate frequent on-and-off pumping periods. Storage capacity is also an important factor when fire insurance rates are established.

Fire demand has a significant impact on the size of a system. Most of the compounds in a distribution system may need to be oversized to meet fire demands. While the total amount of water used for fire fighting or prevention is small, a fire can put very high demands on a system for short periods of time. As fire demands are usually more than twice the normal user demands, facilities are often built to over twice the capacity needed for normal use. The proportional relationship between fire demand and daily demand will vary greatly due to the characteristics of the community. For instance, a community with heavy agricultural use or other use that can be stopped during an emergency might require little or no additional capacity for fire protection. On the other hand, a low-water-use industrial area that requires continuous service might require many times the daily water use for standby capacity for fire protection.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.2A What determines the hydraulic adequacy for a distribution system?

3.2B Why are booster pumps sometimes installed directly on mains?

3.2C Why should construction of dead-end water mains be avoided?

3.3 WATER TRANSMISSION SYSTEMS

Water is delivered from a system's source of supply through transmission lines to the distribution system. The source of supply might be a well, a treatment plant clear well, or a purchased water connection. Surface water supplies, for example streams or impounding reservoirs, and well supplies not meeting drinking water standards would normally be conveyed through a treatment plant before delivery to the distribution system. The source may or may not be under the jurisdiction of another agency. The location of the source determines whether the transmission mains are short or long, and whether the water is transported by gravity or pumping. Wells provide system flexibility since they can be scattered within a distribution system. This can eliminate the need for long transmission mains and may also reduce the requirements for operational storage.

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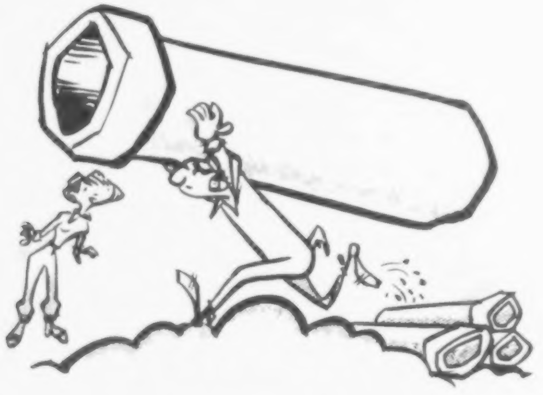
[13] *Head Loss. The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or restrictions caused by fittings. Water flowing in a pipe loses head, pressure or energy as a result of friction losses. Also see FRICTION LOSSES.*

Normally, there are no service connections off of transmission mains or conduits. They are usually made of large pipe with their size depending not only on peak daily flow demand, but also on available operational storage facilities and supplemental supplies such as wells within the system. While many different materials are used for transmission main construction, concrete with a steel cylinder is especially suitable because it is less expensive in the larger sizes.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.3A How can the requirements for operational storage be reduced?

3.3B What type of material is commonly used for large water transmission mains?

3.4 DISTRIBUTION STORAGE[14]

3.40 PURPOSE

A distribution reservoir is a storage facility connected to and serving the distribution system. This reservoir is used primarily to balance out fluctuations in demand which occur over short periods (several hours to several days), to provide local storage in case of an emergency such as a break in a main supply line or failure of a pumping plant, and to control the pressures in the service area.

The principal advantages of distribution storage are:

1. Water can be distributed and stored in advance of a need for water at one or more locations in a service area close to the ultimate user,
2. The demands on the sources of supply, production and treatment works, transmission and distribution mains are more nearly equalized, and their sizes or capacities need not be so great,
3. System flows and pressures are improved and stabilized better to serve the customers throughout the service area,
4. Reserve supplies are provided in the distribution system for emergencies such as fire fighting and power outages, and
5. Costs are reduced. Pumps can be used at a uniform pumping rate which results in cost savings since fewer or smaller pumps are needed. Other power costs can be reduced by pumping only during off-peak hours. Water can be pumped into distribution reservoirs during low usage periods and discharged during periods of high water use. Also, with adequate operational storage, a small water treatment plant might be operated on only one or two shifts per day.

Distribution storage can provide other benefits. Reservoirs may also serve as sand traps to allow the settling of sand and suspended solids in the water. Chlorinated water may be held in covered distribution reservoirs to provide an extended contact time for effective disinfection. Uncovered distribution reservoirs are undesirable due to surface contamination. Water in uncovered distribution reservoirs should be rechlorinated before being returned to the distribution system. If the water supply is from several sources, with one source being of lower quality, the various supplies can be blended together in the reservoir to provide water of consistent and acceptable quality to the consumers.

3.41 Location

Distribution reservoirs should be located as close to the centers of use as possible. Normally, it is more advantageous to provide several smaller storage units in different parts of the system than to provide an equivalent capacity at a central location. The selection of the site or sites usually depends on the elevations available in or near the areas to be served, relative costs of security and access to the sites available, and the visual impact of a storage facility in these locations.

Figure 6.10 shows the hydraulic grade lines for a poorly located storage tank and a properly located tank. When the tank is located away from the area of use, the hydraulic grade line can drop too low and there will be times when adequate pressures can't be maintained in the distribution system. However, when the storage tank is located in the center of use, adequate pressures can be maintained even during periods of high demand.

3.42 Types of Storage

Distribution storage may consist of elevated structures or ground storage at high elevations or a combination of both. In areas which have hills sufficiently higher in elevation than most of the service area and in close-in locations, ground storage may be used. Where natural elevation is inadequate, elevated storage using standpipes and elevated tanks is more efficient. Ground storage is normally more economical than elevated storage and much larger capacities with fewer units can be provided. The useful capacity of standpipes and elevated tanks is limited to the volume of water stored above the elevation at which adequate pressure is created in the connected distribution system. In elevated tanks, this elevation generally coincides with the bottom of the water tank. In standpipes it may be much higher. Large variations in

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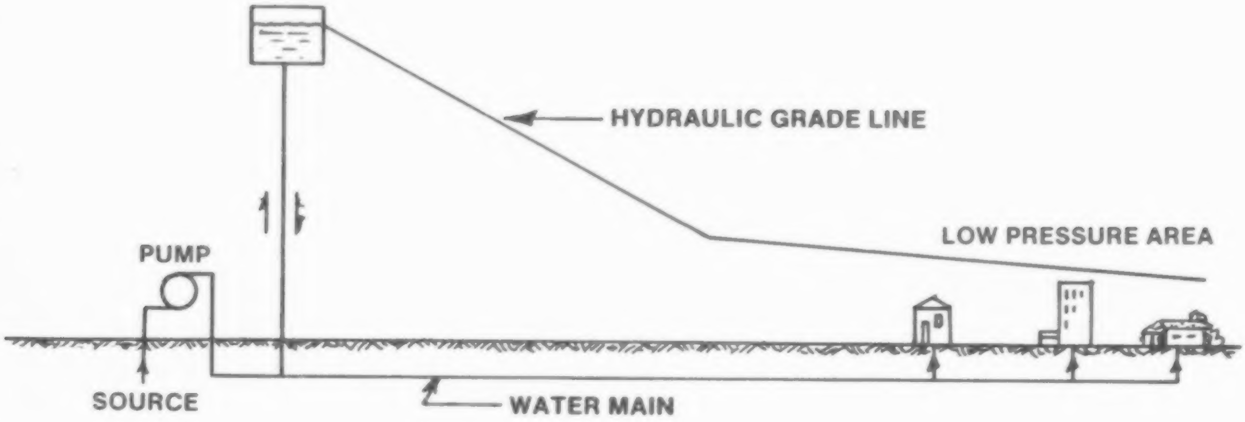
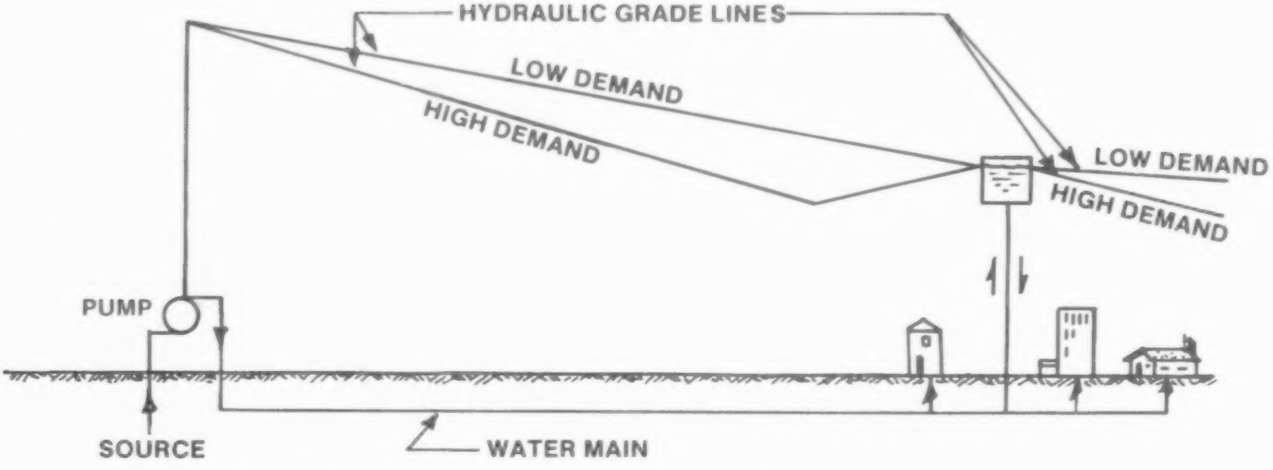
[14] *Also see Chapter 2, "Storage Facilities."*


HYDRAULIC GRADE LINE
LOW PRESSURE AREA
PUMP
SOURCE
WATER MAIN

POORLY LOCATED STORAGE TANK


HYDRAULIC GRADE LINES
LOW DEMAND
HIGH DEMAND
LOW DEMAND
HIGH DEMAND
PUMP
SOURCE
WATER MAIN

PROPERLY LOCATED STORAGE TANK

Fig. 3.10 Elevated storage tank locations

pressure are not desirable in distribution systems. Therefore, water level fluctuations are usually limited to 30 feet (9 m) or less in storage facilities controlling pressures in the distribution system.

3.43 Health and Water Quality Considerations

Open distribution reservoirs are not encouraged and are not approved in many states. Provide an adequate cover for all treated water reservoirs and try to locate and construct all reservoir openings in a manner that protects the water from contamination. Keep manholes and other means of entry securely locked. Cover all vents, drains and overflow outlets with a fine mesh screen to prevent entry of birds, insects and small animals. Take particular care to protect drains and overflows from *CROSS-CONNECTIONS*[15] with any storm drain, sewer line or other source of potential contamination. Drains should be capable of dewatering the reservoir to allow for inspection and cleaning. Also make provisions for the periodic removal of floating material from the water surface while the reservoir is in operation.

Care must be taken with underground facilities because of infiltration of groundwater or other contaminants. Ideally, the intake and outlet should be located on opposite sides to provide for proper circulation of water within the reservoir. However, a common pipe is often used for both the water inlet and outlet. Whenever a single reservoir is taken out of service, do not let the system water pressure within the service area drop below 20 psi (138 kPa or 1.4 kg/sq cm).

Public access should be restricted for safety reasons and to reduce vandalism.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.4A How can the storage of water in covered distribution reservoirs aid disinfection?

3.4B What precautions should be taken with distribution reservoir drains and overflows?

3.5 STORAGE AND BOOSTER PUMPING

Some water systems can rely completely on gravity to bring water from their source to the customer. Most communities, however, must do some pumping to get water from the source to the distribution system. Generally speaking, the topography of the distribution system is such that water must be lifted to the distribution reservoirs. Ground storage pumping to the system is used in some areas where topography does not permit the economical location of storage at the desirable hydraulic elevation of the system. The economy and desirability of pumped storage as compared to elevated storage must be determined for each individual system. Even if pumped storage is found to be more economical overall, its use should be weighed against the proven dependability of elevated storage. In many systems, booster pumps have been installed directly on the mains to increase the available pressure. Pumping is also used in areas where there are relatively few customers located on very high or remote points. They can generally be served adequately by providing a small booster system and pneumatic steel pressure tank operating automatically on pressure control.

Centrifugal pumps are commonly used in water distribution systems. As pump efficiency varies with the load, two or more pumps are often installed in parallel (Figure 3.11) enabling the number of pumps in operation to be varied depending on the flow through the pumping station. A check valve should be provided on the discharge of each pump to prevent backflow when the pump is stopped.

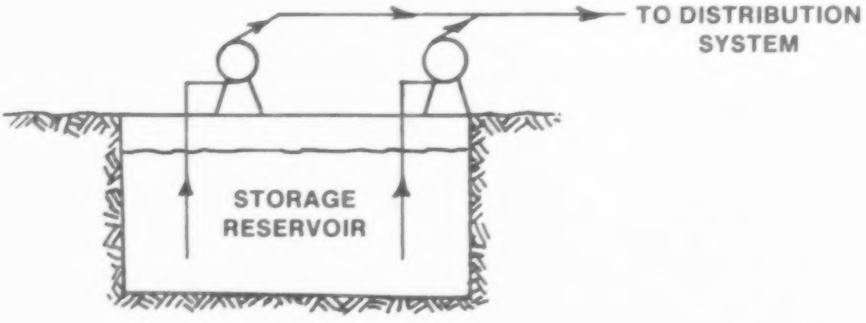


Fig. 3.11 Pumps installed in parallel

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[15] *Cross-Connection. A connection between drinking (potable) water and an unapproved water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross-connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.*

The best source of pumping power is the use of electric motors which are compact and well adapted to automatic control or remote operation. Where the costs of electric power is too high, diesel motors, natural gas engines or steam turbines are used. Standby power should always be provided to protect against possible failure of the main power source. Gasoline engines or motor generators are often used as standby power because of their low initial cost.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.5A What type of pump is used for water distribution systems?

3.5B What is the best source of power for distribution system pumps?

End of Lesson
1 of 5 on
DISTRIBUTION
SYSTEM
FACILITIES

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 1 of 5 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. What is the purpose of a water distribution system?
2. Why must a continuous positive water pressure be maintained in the distribution system at all times?
3. How are negative pressures created in a distribution system during a fire?
4. What problems may be encountered with distribution system underground storage reservoirs?

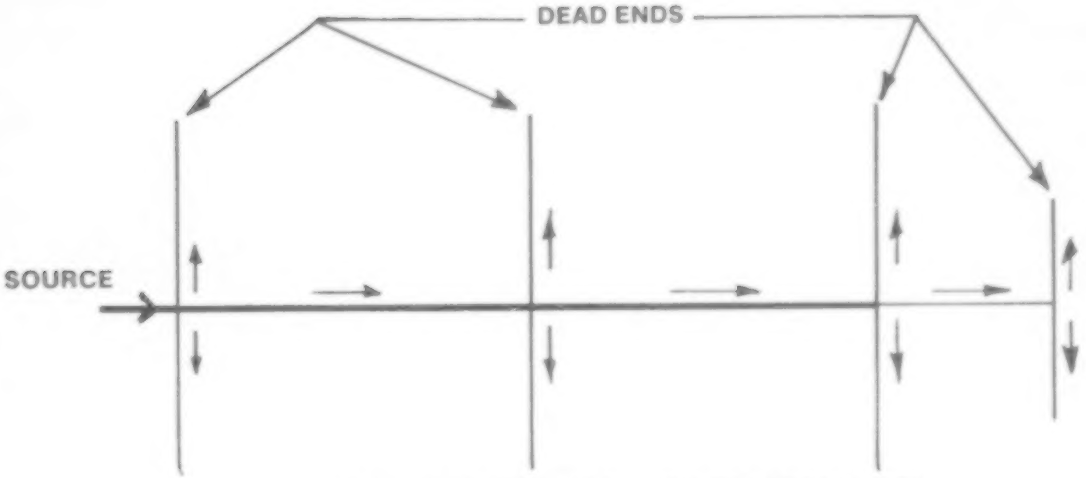
CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 2 of 5 Lessons)

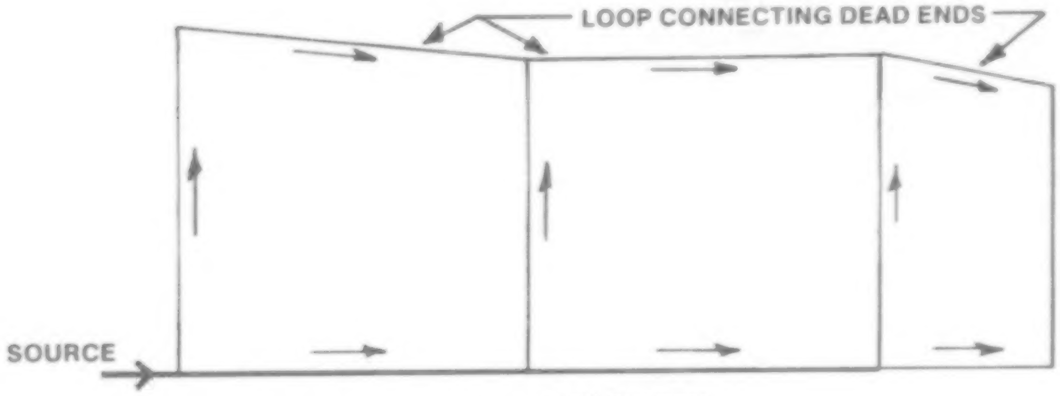
3.6 WATER MAINS AND APPURTENANCES

3.60 Layout

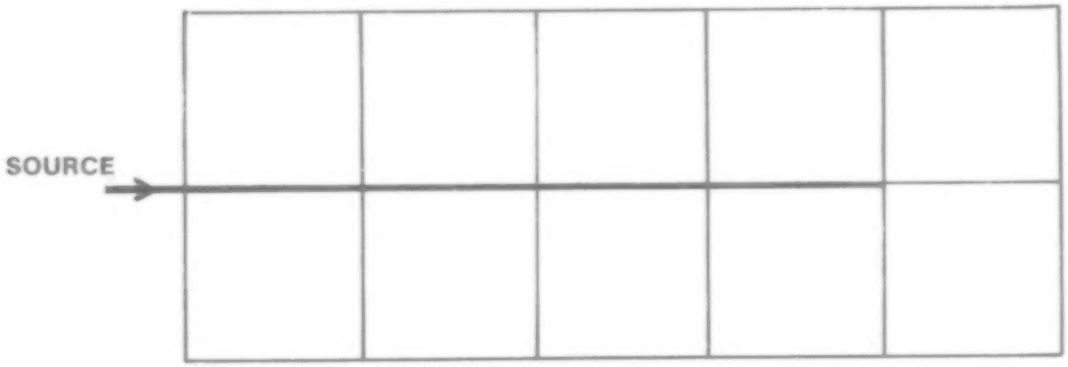
Water distribution system mains are laid out in grid, loop of tree (branching) systems as shown in Figure 3.12. Most systems contain features of each type of layout, although the grid system is probably most common, particularly in large cities. Tree or branching systems produce dead-end lines which can cause taste and odor water quality problems. These lines must be frequently flushed and should be avoided wherever possible. Grid or loop systems permit greater water flow to an area when there is a fire or other source of high demand because water is being carried to any particular location from more than one direction. Unfortunately, some grid systems may include dead ends. A tree system consists of a single large main that decreases in size as it extends into the distribution area. Branches take off from the main at right angles with sub-branches from each branch. Branching patterns are more evident on the outskirts of a community, while grid patterns are found within the built-up portions of a community.


DEAD ENDS
SOURCE

TREE (BRANCHING) SYSTEM WITH DEAD ENDS


LOOP CONNECTING DEAD ENDS
SOURCE

LOOP SYSTEM



GRID SYSTEM

Fig. 3.12 Typical layouts of water distribution systems

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.60A Dead-end water mains can cause what type of problem?

3.60B List two advantages of grid or loop water distribution systems.

3.61 Pipe Features

The basic requirements of pipes for water distribution systems are adequate strength, durability, maximum corrosion resistance and no adverse effect on water quality. Pipe strength must be sufficient to resist a variety of forces. Exterior forces such as backfill cover over the pipe, the weight of passing traffic and other similar forces must be resisted. Pipes are also subjected to internal water pressures such as delivery pressure, surges and water hammer. Pipe must also be durable and exist for a long time without deterioration. Good, durable pipe will retain a smooth inside surface with satisfactory flow characteristics throughout its service life. The inner surface of the pipe should not react with water and should resist corrosion. The exterior surface of the pipe also must be corrosion resistant. If the pipe is electrically conductive, then *CATHODIC PROTECTION*[16] may be needed. Tastes, odors, chemicals, or any other undesirable characteristics must not be imparted to the water by the pipe.

Also of importance is the ease with which the pipe can be handled and installed. Some installation features that are significant are weight, jointing characteristics, available sizes, and ease of tapping the line. The lighter the pipe, the easier it is to handle. Jointing is important not only for ease of installation but also with regard to any possible flexibility or deflection. Pipe should be available in all the commonly used sizes. If other lines (such as service lines) are to be attached to the pipe, the ease with which the pipe can be tapped is an important consideration.

The pressure rating of the pipe must be adequate to handle the pressures it will encounter in the system. Pressure ratings refer to the working pressure to be expected within a pipe and may take into account the internal pressure and a safety factor. Four classes of working pressure are commonly encountered — 100, 150, 200, and 250 psi (690, 1034, 1380 and 1724 kPa or 7, 10.5, 14 and 17.5 kg/sq cm).

Pipes may rupture or be crushed when subjected to external or internal pressures that exceed its ratings. Other common types of breakage are shear (cutting) and beam (bending) breakage. A shear break can occur when the earth moves, such as during an earthquake. Beam breakage may result when a pipe is unevenly supported along its length.

The size of a pipe must be sufficient to carry anticipated flows. The desirable minimum pipe diameter is 6 inches (150 mm) and pipes should certainly not be less than 4 inches (100 mm) in diameter.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.61A List the forces water distribution system pipes must be capable of resisting.

3.61B List the important installation features of water distribution pipes.

3.62 Pipe Types

A wide variety of pipe materials is available for carrying water under pressure including plastic, asbestos-cement, ductile iron, steel and reinforced concrete. *SERVICE PIPES*[17] are made of copper, plastic, iron, steel, asbestos-cement and brass.

3.620 Ductile Iron Pipe (Figure 3.13)

Ductile iron pipe is manufactured in sizes ranging from 2 to 54 inches (50 to 1350 mm) in diameter. Transmission lines, distribution lines or in-plant piping may be made of ductile iron. When properly coated and lined, it provides an extremely long service life.

Two types of cast iron pipes may be encountered, grey cast iron and ductile iron pipe. Grey cast iron is tough and is easily tapped. Ductile iron is similar, but is stronger, less rigid, lighter and offers corrosion resistance equal to or better than grey cast iron. Ductile iron will resist bending and twisting without breakage. Both types of pipe can withstand high pressures. Ductile iron pipe is the only type being manufactured today.

Ductile iron pipe is lined on the inside to prevent corrosion, including tuberculation (too-BURR-que-LAY-shun) which is the pitting or growth of clumps of material which increase friction, thus reducing flows. Cement mortar or other available linings are used to produce a smoother pipe interior. A lined pipe may have one-half the friction loss of an unlined pipe. To reduce external pipe corrosion, bituminous coatings or a polyethylene wrap are commonly used.

3.621 Steel Pipe (Figure 3.14)

Steel pipe has long been popular in water systems. This pipe is available in sizes from ½ to 144 inch (12.5 to 3500 mm) in diameter. Steel pipe is lighter than ductile iron or concrete, strong, withstands high operating pressures, and can be designed in thickness and strength to meet the most severe conditions. This pipe has high tensile (pulling or

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[16] *Cathodic Protection (ca-THOD-ick). An electrical system for prevention of rust, corrosion, or pitting of steel and iron surfaces in contact with water or soil.*

[17] *Service Pipe. The pipeline extending from the water main to the building served or the consumer's system.*

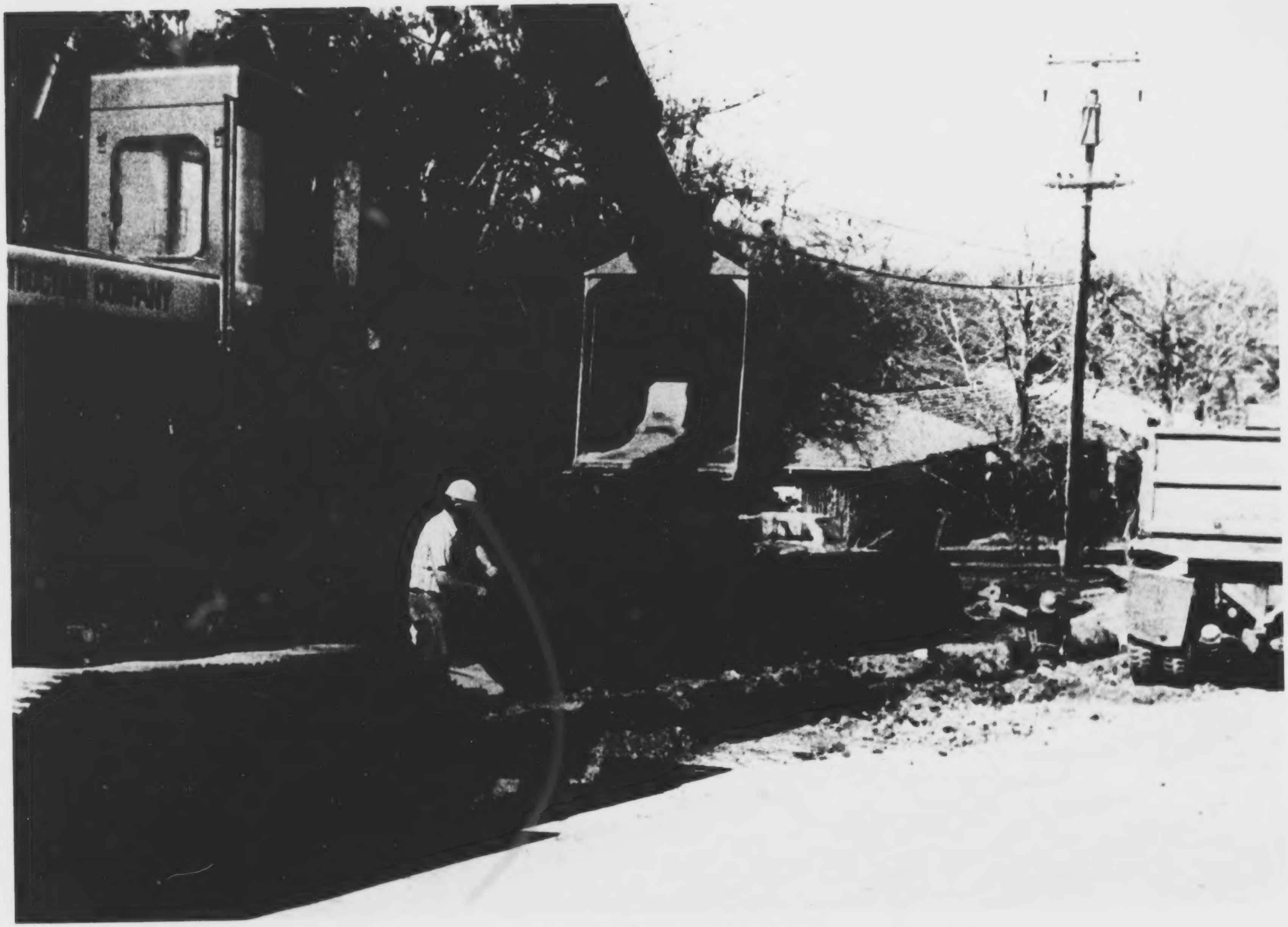

Fig. 3.13 Installation of ductile iron pipe
(Courtesy of the Ductile Iron Pipe Association)

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Fig. 3.14 Coal tar enamel lined steel pipe

(Permission of Steel Plate Fabricators Association, Inc.)

stretching) strength, some flexibility, is easily installed and jointed, low in cost, readily welded together, and easily assembled, handled and transported. However, steel pipe is more subject to corrosion and requires a lining or coating to maintain its service life. This pipe has low resistance to external pressures in the larger sizes. Though protective coatings and linings can be applied to increase its durability and service life, these linings are sometimes damaged because of the flexibility of the pipe as it bends under trench loads. Coatings and linings are usually of a bituminous material or a cement mortar. An epoxy lining is also sometimes used. The exterior of a steel pipe can be coated with epoxy or mastic; it could be *GALVANIZED*[18]; or a protective wrap might be used. Cathodic protection may also be provided to prevent corrosion.

3.622 Concrete Pipe

Three types of concrete pipe can be obtained — steel cylinder (not *PRESTRESSED*[19]), steel cylinder (prestressed), and non-cylinder (not prestressed). Concrete pipe is available in sizes 12 inches (300 mm) and larger. This pipe can actually be made in any size and has been produced in diameters up to 240 inches (6000 mm). In large sizes it is usually less expensive than any other kind of pipe. Concrete pipe is durable, has good corrosion resistance and low maintenance features, and is easily installed. The inside of the pipe has been found to remain smooth for more than a hundred years of service. Prestressed concrete is strong, with normal working pressures up to 250 psi (1724 kPa or 17.5 kg/sq cm). However, reinforced concrete which is not prestressed is not very strong and can only take up to 50 psi (345 kPa or kg/sq cm) working pressure. The disadvantages of concrete pipe are that the pipe is heavy, may be hard to tap, needs special fittings and may deteriorate in aggressive (corrosive) soils. If the water is aggressive (corrosive), a higher water pH may be encountered for one or two years after the installation of concrete pipe.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.62A How can the external corrosion of ductile iron pipe be reduced?

3.62B Steel pipe may be lined with what types of materials?

3.62C What types of coatings may be applied to steel pipe?

3.62D List the major disadvantages of concrete pipe.

3.623 Asbestos-Cement Pipe

Asbestos-cement (AC) pipe is a relatively popular pipe material. This pipe is made of asbestos fiber, silica sand, and cement. The asbestos fibers provide much of the pipe's strength. Asbestos is a mineral that is almost indestructible. This pipe material will not burn, deteriorate, or corrode, and has a high tensile strength. Available pipe sizes range from 4 to 42 inches (100 to 1050 mm) in diameter. AC pipe is light and weighs approximately half as much as ductile iron pipe of equal size and class. This pipe is easy to handle and join. Also, it costs less to transport because of its light weight. Since AC pipe is non-metallic, it is completely immune to *ELECTROLYSIS*[20] and cannot tuberculate as do metal pipes. The pipe has a smooth, uniform bore with a high carrying capacity that holds up for a long time because the material does not corrode. AC pipe is easily tapped, cut and machined in the field. One operator with light-weight cutting and machining tools can cut the pipe right on the job site.

The disadvantages of AC pipe are its low flexual strength (breaks when it is bent) in small sizes and its vulnerability to impact damage. AC pipe is difficult to locate when buried and cannot be thawed out using electrical methods because the material is nonconductive. Asbestos fibers have been known to leach out of the pipe in soft waters. People who work with AC pipe may be exposed to a health hazard if asbestos fibers are inhaled when the pipe is cut or machined. Respirators must be worn whenever there is a possibility that asbestos particles can become airborne when working with asbestos-cement pipe.

3.624 Plastic Pipe (Figure 3.15)

Plastic pipe is commonly used for distribution and service lines in water systems (Figure 3.15). Plastic pipe is used for water distribution mains in many parts of the country. Three types of plastic material are in general use: PVC (polyvinyl chloride), PE (polyethylene), and PB (polybutylene). The pipe is available in a wide range of sizes; however, PVC is the only one that goes up to 16 inches (400 mm) in diameter.

All plastic pipe has an exceptionally smooth interior surface and, therefore, low friction head losses. The pipe materials are chemically inert which means they are completely corrosion free. PVC piping systems average 30 percent less in cost than steel pipe because of savings in installation and long-range corrosion-free maintenance.

3.625 Types of Service Pipe

The service pipe is the pipeline extending from the water main to the building served or the customer's system. Normally, ¾ to 1½ inch (9 to 38 mm) pipe is used. The ability

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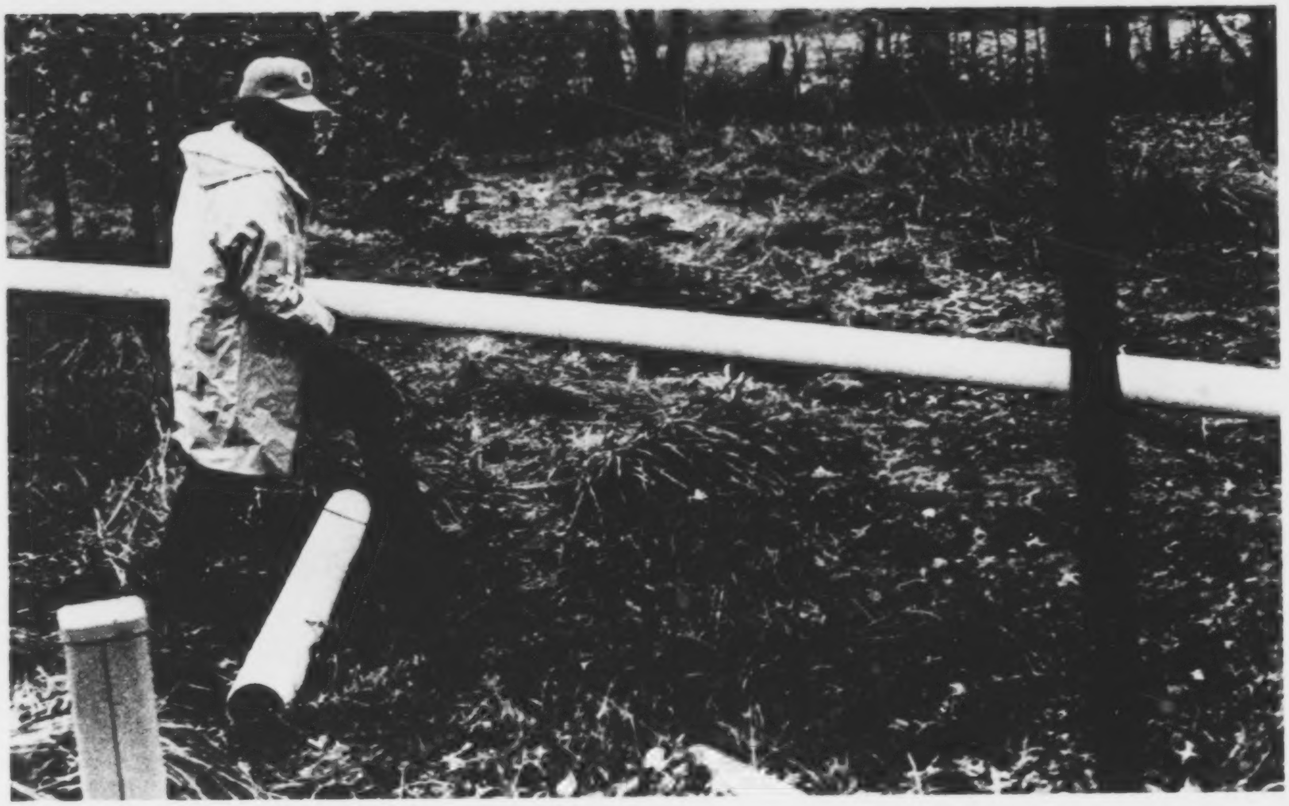
[18] *Galvanize. To coat a metal (especially iron or steel) with zinc. Galvanization is the process of coating a metal with zinc.*

[19] *Prestressed. Prestressed pipe has been reinforced with wire strands (which are under tension) to give the pipe an active resistance to loads or pressure on it.*

[20] *Electrolysis (ee-leck-TRAWL-uh-sis). The decomposition of material by an electric current.*



PVC pipe's light weight makes movement by one person an easy task.

Fig. 3.15 Plastic pipe

(Permission of Uni-Bell Plastic Pipe Association)

of the pipe material used to resist internal and external corrosion is the most important factor in the useful life or service lines. Most service lines use copper, PVC, PE, PB or, in special cases, reinforced plastic pipe. Other materials are also used, such as ductile iron, black and galvanized wrought iron, steel, asbestos-cement, and brass. In some older systems, lead service lines still exist. These lines are no longer acceptable. Lead should be replaced because of the potential for lead (which is a toxic material) to enter the water.

3.626 Summary

There are no rules which will tell you which type of pipe to select for a specific installation. Important considerations include cost of pipe and installation and also the corrosive conditions of the soil and water. Another important factor is the water pressures and external pressures the pipe must withstand.

Plastic pipe is very popular in small installations followed by asbestos cement. Ductile iron pipe is used in steep hills where pressure differences can be great. For pipes 24 inches (600 mm) and larger reinforced concrete pipe or cement lined or coated steel pipe is often used.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 151.

3.62E What are the disadvantages of asbestos-cement pipe?

3.62F List the three types of plastic material used for plastic pipe.

3.62G What are the most common materials used for service lines?

3.62H Why should existing lead service lines be replaced?

3.63 Joints

Joints connect two lengths of pipe. Different types of joints are used depending on the pipe materials, conditions of installation, and degree of joint deflection (change in direction or alignment) needed. Joints must provide a watertight seal. They should be easily installed, durable and corrosion resistant.

3.630 Ductile Iron Pipe

Push-on and mechanical joints are most often used for ductile iron pipe. Flanged, restrained, flexible and sleeve joints are also used.

Push-on joints are the most frequently used type of joints. They are used with bell and spigot pipe which has an enlarged diameter or bell at one end and a spigot at the other end which fits into and is laid in the bell. Inside the bell there is a groove in which a heavy rubber gasket rests.

When the joint is made in the field, the gasket is inserted into the bell, the spigot end is coated with a lubricant film, and the spigot is pushed "home." In the larger pipe sizes, a jack is often used to push or pull the spigot into place. The assembly of a push-on type joint is shown in Figure 3.16.

Mechanical joints (Figure 3.17) are easy to install and are flexible. The standard mechanical joint consists of (1) a specially shaped hub, (2) a ring or gasket shaped to fit the pipe's bell, and (3) an iron follower ring or gland which forces the gasket into and against the hub by means of bolts passing through lugs cast on the bell. The gaskets are generally plain rubber. Joint deflection of a few degrees is possible. Assembling a mechanical joint is very simple and requires only a ratchet wrench.

The Dresser (Figures 3.18 and 3.19) and Victaulic couplings (Figure 3.20) are special types of mechanical joint couplings. The compression (Dresser) coupling, which joins plain-end ductile iron pipe, provides a sleeve-type joint. A ductile iron middle ring is used and a leak-proof joint is obtained at each end of the middle ring by compressing two resilient gaskets with bolted follower rings. The gaskets absorb vibration and pipe movements. These joints allow for moderate deflection and are used to span short gaps.

Victaulic couplings are generally used on smaller pipe. In this type of coupling, each end of the pipe has a groove or shoulder which receives the sides of a trough-shaped metal housing in which there is a similarly shaped rubber gasket. A clamp fits over the grooves and makes the connection. The drawback of this coupling is that the groove weakens the pipe wall.

A flanged joint is one that is made by simply bolting the flanges of two pipes together with a resilient gasket between the flanges. Flanged joints are not flexible and are usually not installed when a pipe is buried.

Restrained joints are used where there is a lack of space to lock a joint in place to prevent movement, or where there is a possibility the soil behind a fitting will be disturbed. They are usually installed at the critical fitting and for a certain number of pipe lengths on each side of the fitting.

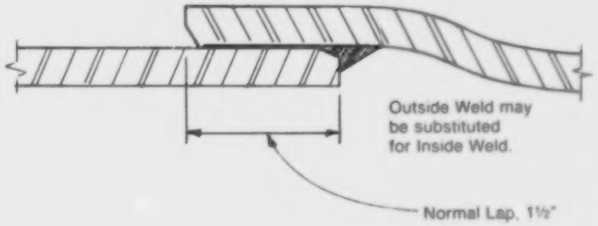
A flexible joint is any joint between two pipes that permits one of them to be moved without disturbing the other pipe. They are used at river crossings and other underwater installations and are similar to a ball and socket joint.

3.631 Steel Pipe[21]

Steel pipe lengths can be joined together in the field by many different methods to effect rigid or flexible connections, as follows:

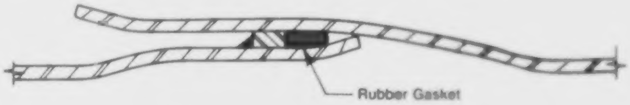
1. Bell & Spigot Lap Welded Joint,
2. Bell & Spigot Rubber Gasket Joint,
3. Harness Joint — Bell & Spigot,
4. Carnegie Shape Rubber Gasket Joint,
5. Butt Welded Joints,
6. Butt Strap Joint for Welding,
7. Mechanically Coupled Joints, and
8. Flanged Joint for Bolting

1. *BELL & SPIGOT LAP WELDED JOINTS*

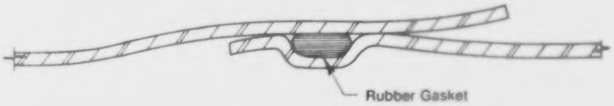


The Bell and Spigot lap welded joint is widely used because of its flexibility, ease in forming and joining, water-tightness and simplicity. Small angle changes can be made in this joint. The joint may be welded on either the inside or outside with a small fillet weld.

2. *BELL & SPIGOT RUBBER GASKET JOINTS*



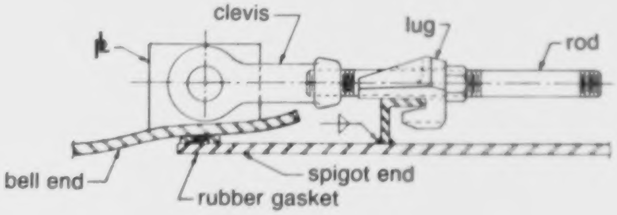
a. Formed rubber gasket joint, usually applied to large diameter water pipe.

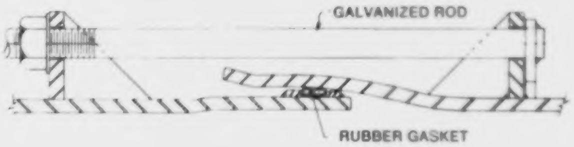


b. Rolled-groove rubber gasket joint, usually applied to small diameter water pipe.

Bell and Spigot Rubber Gasket Joints simplify laying the pipe and require no field welding. They permit flexibility, water-tightness, lower installation costs, and elimination of bell-holes.

3. *HARNESS JOINT* — Bell & Spigot Rubber Gasket.





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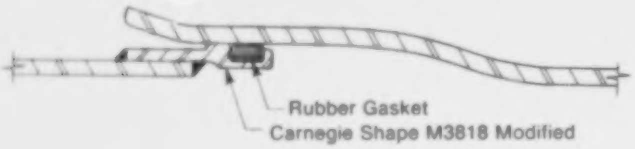
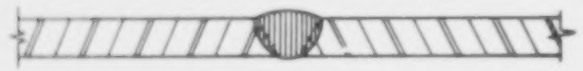
[21] *This section reproduced from WELDED STEEL PIPE by permission of Steel Plate Fabricators Association, Inc.*

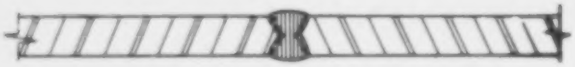
4. *CARNEGIE SHAPE RUBBER GASKET JOINTS*



5. *BUTT-WELDED JOINTS*



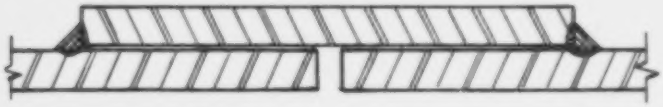
a. Single-V Butt-Welded



b. Double-V Butt-Welded

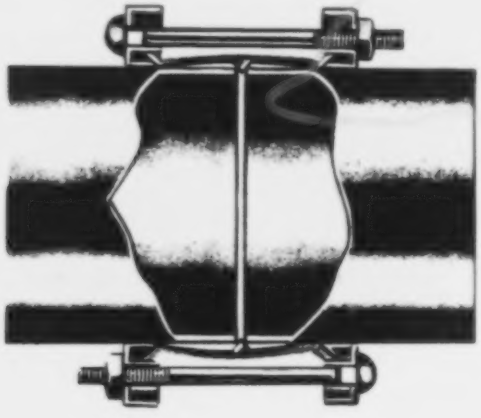
Butt-welded joints will develop full strength, but will require more care in cutting and fitting up in the field if changes in alignment or profile occur frequently. This joint is not commonly used.

6. *BUTT STRAP JOINT FOR WELDING*

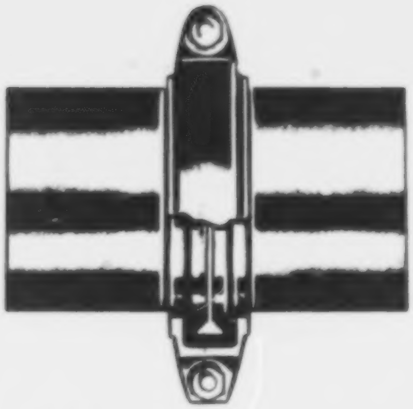


The butt strap is a closure joint used for joining ends of pipe when adjustments are required in the field.

7. Mechanical Couplings



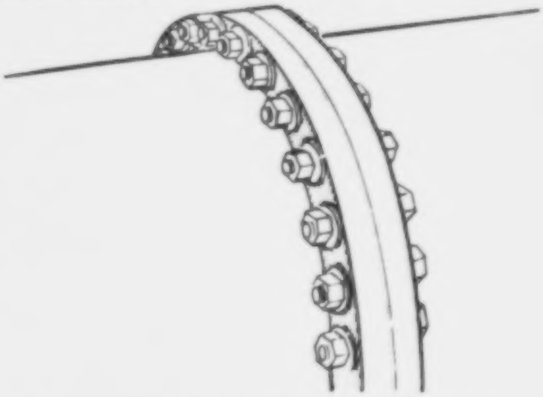
a. Sleeve type



b. Grooved and shouldered type

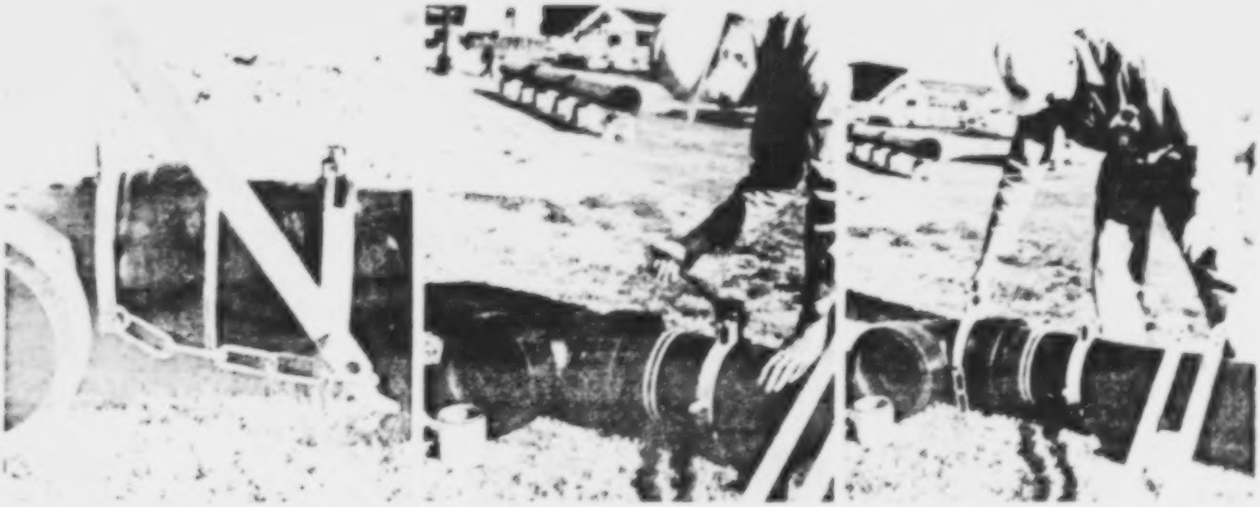
Mechanical couplings provide ease of installation and flexibility and are represented by the sleeve and clamp type of coupling.

8. *FLANGED JOINTS*



Flanged joints are not generally used for field joints on large diameter steel pipe because of their high cost and lack of flexibility. They are advantageous, however, for special conditions, such as connections to flanged gate valves, bridge crossings, meters, and for field connections by unskilled labor.

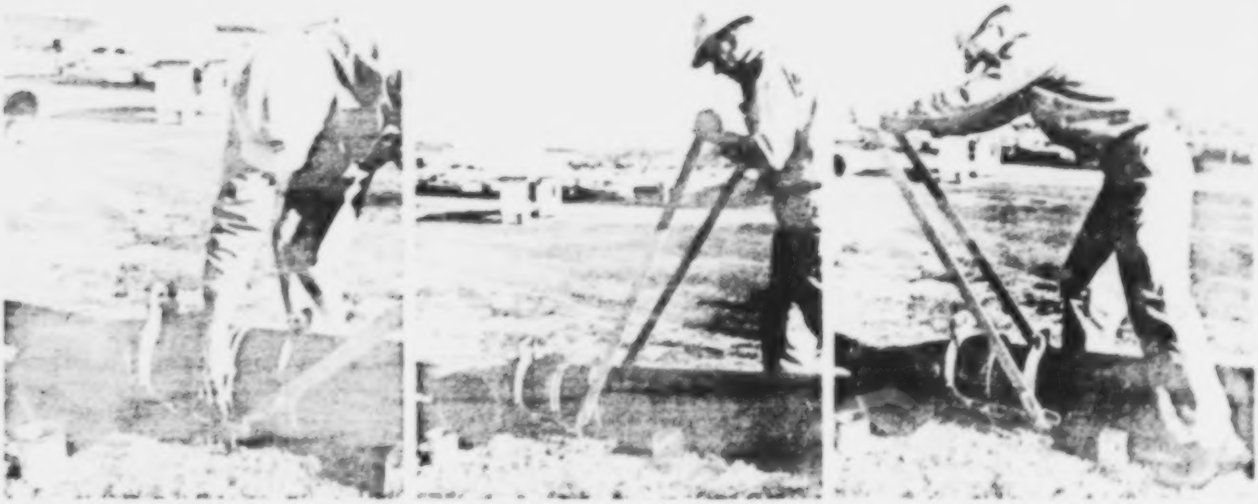
Fig. 3.17 Mechanical joint
Slide gland into position, insert bolts and tighten nuts
(Source: *HANDBOOK OF CAST IRON PIPE*)



Assembly tool that is available from U.S. Pipe for asembling Tyton Joint fittings. The assembly tool consists of a bell yoke with chain attached, hinged pipe clamp, and a pair of handles.

1. Attach the pipe clamp to the pipe about twelve inches from the spigot end making sure that the swing bolt is on the top of the pipe. Tighten the swing bolt.

2. Place the yoke on the fitting behind the bell.



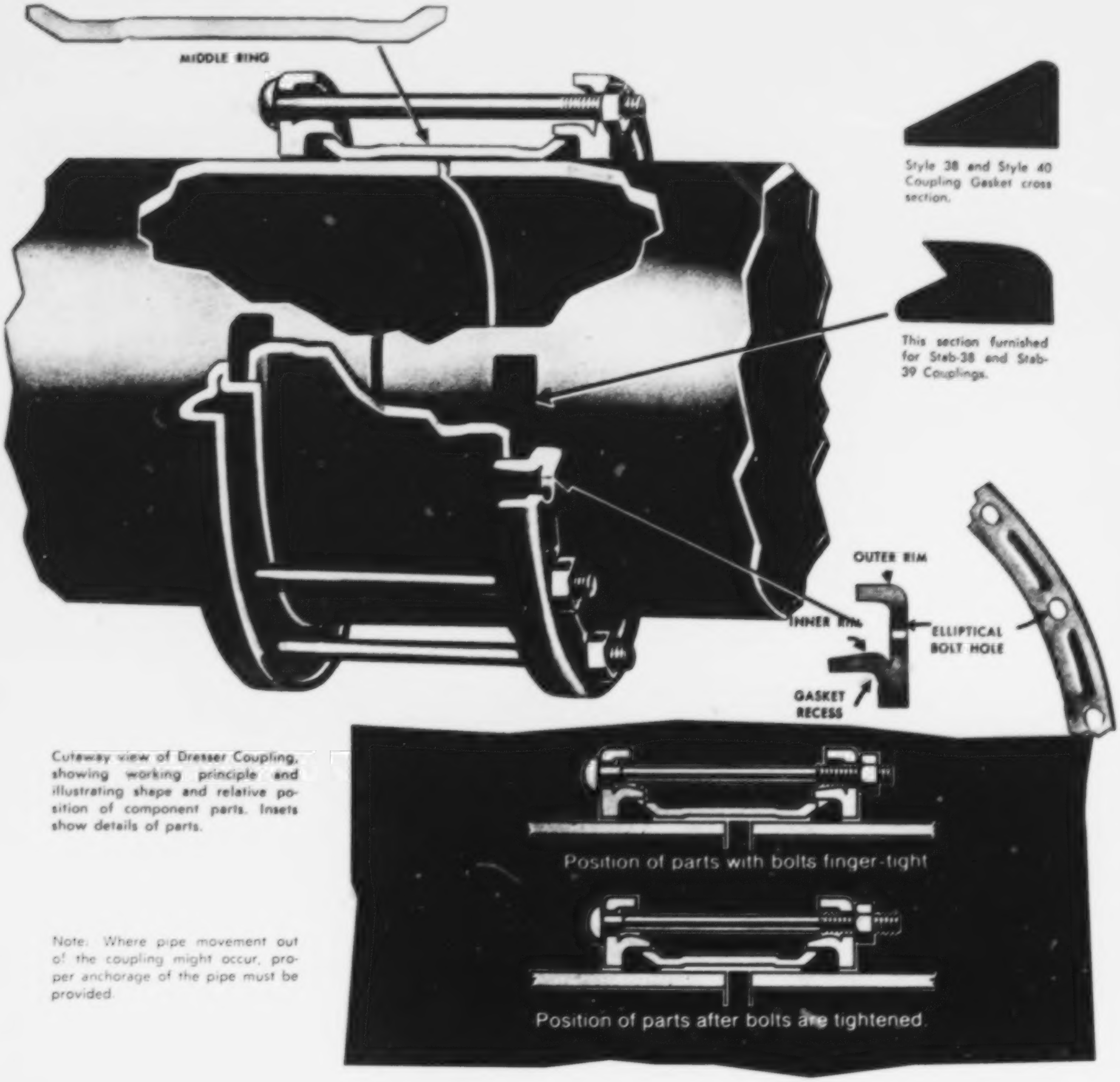
3. Place the two handles on the pivot pins of the pipe clamp and couple the chain to the handles.

4. Assemble the joint by pushing on the handles which are shown in position for the start of the assembly. The two handles operate independently helping to maintain the fitting in straight alignment throughout the assembly.

5. The completed assembly. Note that the second stripe is at the face of the bell.

Fig. 3.16 Assembly of a push-on type joint

(Permission of U.S. Pipe)


MIDDLE RING
OUTER RIM
INNER RIM
ELLIPTICAL BOLT HOLE
GASKET RECESS
Position of parts with bolts finger-tight
Position of parts after bolts are tightened.

Style 38 and Style 40 Coupling Gasket cross section.

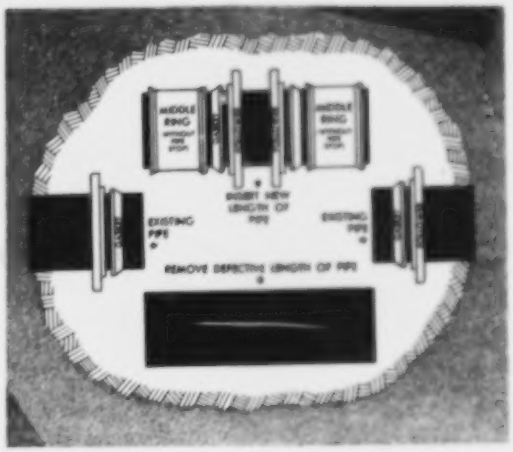
This section furnished for Stab-38 and Stab-39 Couplings.

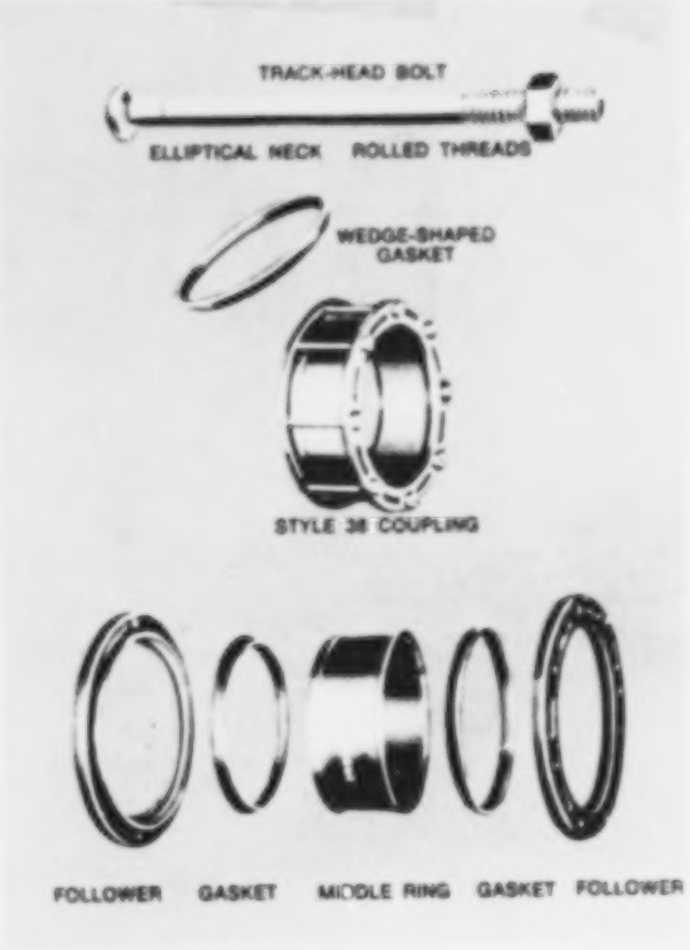
Cutaway view of Dresser Coupling, showing working principle and illustrating shape and relative position of component parts. Insets show details of parts.

Note: Where pipe movement out of the coupling might occur, proper anchorage of the pipe must be provided.

Fig. 3.18 Cutaway view of Dresser coupling

(Permission of Dresser Manufacturing Division, Dresser Industries, Inc.)


MIDDLE RING
MIDDLE RING
INSERT NEW LENGTH OF PIPE
EXISTING PIPE
EXISTING PIPE
REMOVE DEFECTIVE LENGTH OF PIPE


TRACK-HEAD BOLT
ELLIPTICAL NECK
ROLLED THREADS
WEDGE-SHAPED GASKET
STYLE 38 COUPLING
FOLLOWER
GASKET
MIDDLE RING
GASKET
FOLLOWER

EASY WAY TO REPAIR A SECTION OF PIPE . . .

Sleeve-in a new section of pipe with Dresser Style 38 Couplings. Diagram at left shows how Style 38 Couplings may be used to make "cut-ins" into piping for repair. Valves or fittings can be inserted in the same way. **With Stab-38® Couplings the whole coupling slips on the pipe ends without disassembly.**

Fig. 3.19 Repairing pipe with a Dresser coupling

(Permission of Dresser Manufacturing Division, Dresser Industries, Inc.)

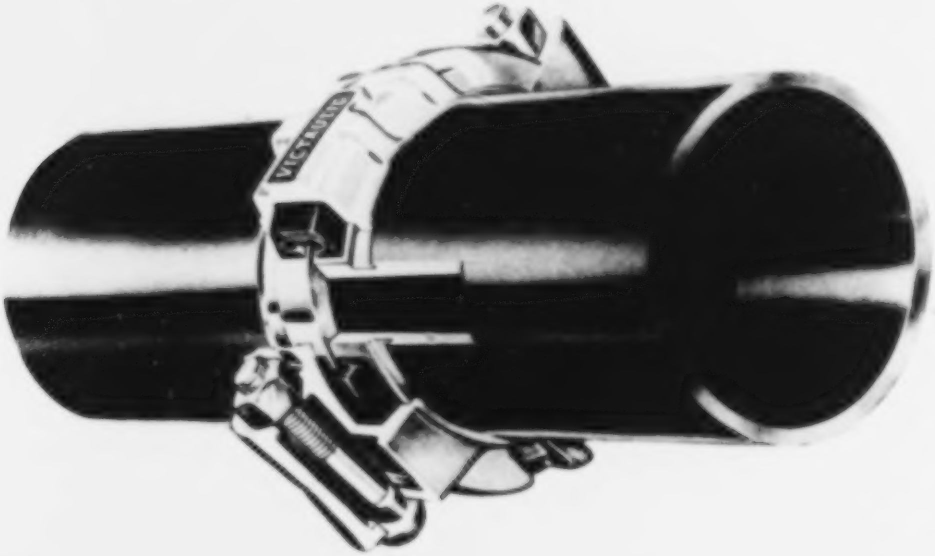


Fig. 3.20 Victualic coupling used for ductile, grooved, iron pipe

(Permission of Victaulic Company of America)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.63A List the basic requirements for a good pipe joint.

3.63B What types of joints are most commonly used for ductile iron pipe?

3.63C What types of joints are used to join steel pipe?

3.632 Steel Cylinder Concrete Pipes

Steel cylinder concrete pipe is normally joined using a modified bell and spigot (Figure 3.21). The sealing element consists of a rubber gasket; steel rings in the bell and spigot are usually provided. The outside joint space is normally completely filled with cement mortar to protect the joint rings against external corrosion. Both the inner and outer space is filled with mortar. Concrete pressure pipe may be installed with or without a steel cylinder depending on the conditions.

3.633 Asbestos-Cement Pipe

Asbestos-cement pipe is joined by special sleeve couplings which are also made of asbestos-cement (Figure 3.22). These couplings are machined to fit over the pipe's machined ends. They consist of a sleeve grooved to receive two interior rubber gasket rings which provide a water-tight seal. Couplings 3 to 12 inches (75 to 300 mm) in diameter allow five degrees deflection, and those with diameters from 14 to 24 inches (350 to 600 mm) permit a deflection of three degrees. Couplings should be able to take the same pressure as the pipe with which they are used and should be marked accordingly. The joint is normally jacked or pulled onto the pipe. In some pipe, the coupling comes already installed on one end; consequently, a push-on or slip type joint can be used.

Cast iron (ductile iron) fittings including elbows, tees, crosses, reducers, valves and hydrants are available with bells for connections to asebestos-cement pipe. Special adaptors are available to connect asbestos-cement pipe to ductile iron pipe at either mechanical joint or poured bell fittings. Asbestos-cement pipe also can be connected to steel or plastic pipe by the use of adaptors.

3.634 Plastic Pipe

The jointing methods for plastic pipe vary depending on the type of pipe material. For PVC (polyvinyl chloride) pipe, solvent weld or bell and spigot joints maybe used. The solvent weld consists of a solvent that causes both pieces of pipe to be cemented together. The seal in the bell and spigot pipe is provided by an O-ring. A gasketed joint is the usual type used for PVC pipe. The pipe may be an integral (attached) bell design or a separate sleeve-type coupling may be used. Schedule 80 and heavier wall PVC pipe may be threaded. PE (polyethylene) and PB (polybutylene) pipe are joined using a heat-fusion method. Threading of these materials is not recommended.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.63D How are the joint rings for concrete pressure pipe protected against external corrosion?

3.63E How much deflection is allowed in the couplings of asbestos-cement pipe?

3.63.F What types of joints are used for PVC pipe?

3.64 Pipe Protection

Pipe must be protected to maintain its strength, pipe performance and carying capacity. Protection must be provided to control corrosion and to prevent leakage, rupture or collapse.

A number of corrosion control methods[22] are available. Some of the commonly used techniques and materials are listed below:

1. Non-metallic pipe materials such as asbestos-cement, reinforced concrete, and plastic.
2. Non-metallic coatings to protect metals such as coal tar enamels (bituminous), coal tar-epoxy enamels, asphaltics, cement mortar, epoxy resins, vinyl resins and paints, inorganic zinc silicate paints, and organic zinc paints. Pipe exteriors may also be protected with a loose polyethylene wrap or sleeve. Any protective coating must be continuous, without holes or breaks, or the corrosive attack will be concentrated on the exposed spots.
3. Metallic coatings to protect metals such as zinc (galvanizing) or aluminum.
4. Chemical treatment to deposit a protective coating or film on the pipe using calcium carbonate, sodium hexametaphosphates and silicates, pH adjustment, removal of dissolved oxygen, and removal of free carbon dioxide.
5. Electrical control using cathodic protection.

Often, a combination of the above methods must be used. The first choice is the proper use of non-corrosive metals and/or mechanical coatings. Next, chemical control methods may be tried as a supplementary measure. Finally, cathodic protection is tried if circumstances indicate that this method is appropriate.

Steel pipe is especially susceptible to corrosion and needs a great deal of protection. The inside and outside of the pipe are either protected with cement mortar, cold-applied mastic, or hot coal tar enamel. Small pipe up to four inches (100 mm) in diameter is galvanized. If steel pipe is exposed above ground, the outside is usually protected with paint.

In addition to corrosion control, other protection measures are needed to prevent pipe damage.

1. Care must be exercised when loading, unloading and installing pipe. Pipe should not be dropped or allowed to strike other pipe. The bedding and backfilling material must be carefully chosen and placed in the trench. Asbestos-cement pipe is especially susceptible to puncture by sharp rocks or damage by heavy rocks which may be located directly next to the pipe. This is especially likely to occur if heavy loads or trucks go over the pipe. Improper, non-uniform bedding will provide only poor support and weaken the pipe.

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[22] *Also see Chapter 8, "Corrosion Control," in WATER TREATMENT PLANT OPERATION, Volume I.*

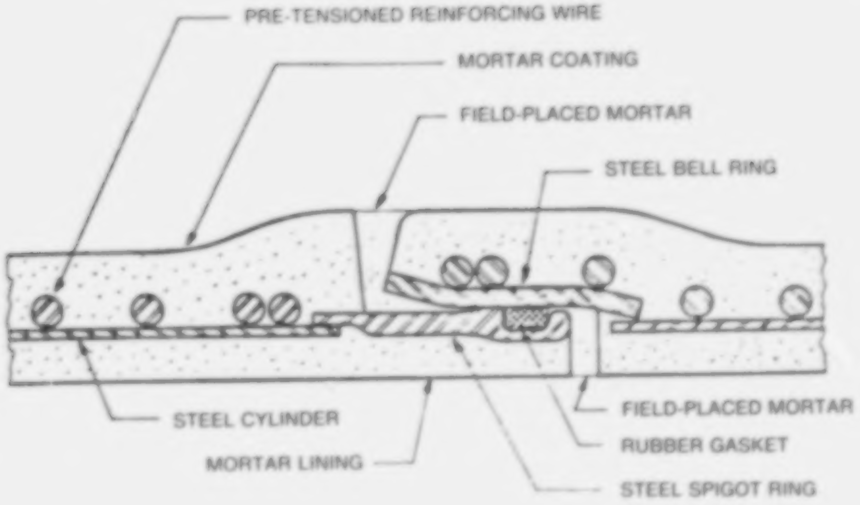

PRE-TENSIONED REINFORCING WIRE
MORTAR COATING
FIELD-PLACED MORTAR
STEEL BELL RING
STEEL CYLINDER
MORTAR LINING
FIELD-PLACED MORTAR
RUBBER GASKET
STEEL SPIGOT RING

Fig. 3.21 Steel cylinder concrete pipe modified bell and spigot coupling
(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*
by permission. Copyright 1976, the American Water Works Association)

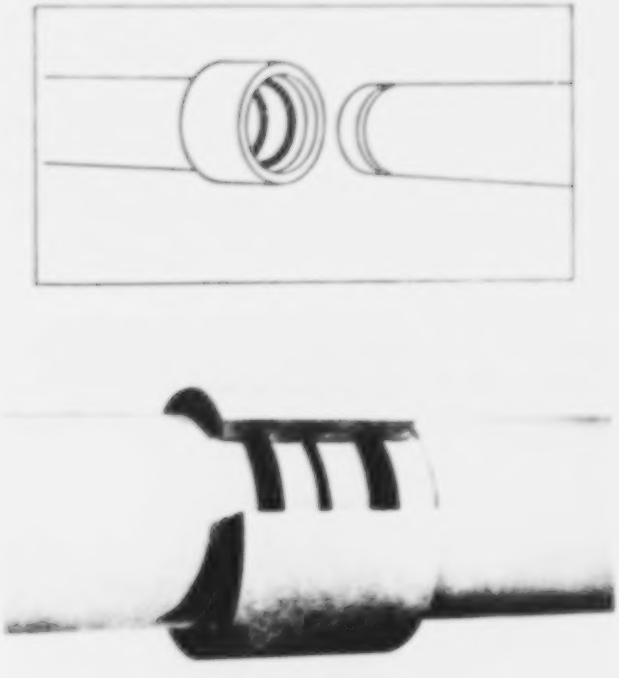


Fig. 3.22 Asbestos-cement pipe coupling
(Permission of Johns-Manville Corporation,
a Subsidiary of Manville Corporation)

2. Where increased strength is needed, concrete encasement of a steel cylinder slipped over the pipe is often used. This is done in stream beds where heavy floods may be encountered. This type of protection may also be provided to a water or sewer line (or both) if they get too close to one another. Special sewer pipe material may also be required.
3. Vacuum, pressure-relief and pressure-reducing valves will prevent pipe damage from negative or excessively high pressures.
4. Thrust blocks are used to anchor pipes and fittings, and to keep them from moving or being pulled apart when there is a change in direction of the pipe, a sudden increase in velocity, or a sudden stoppage of flow.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.64A List the most commonly used corrosion control methods.

3.64B How can steel pipe be protected from corrosion?

End of Lesson 2 of 5 on DISTRIBUTION SYSTEM FACILITIES

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 2 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 1.

5. What are the basic requirements for water distribution system pipes?
6. What are the advantages of using ductile iron pipe?
7. Discuss the advantages of asbestos-cement pipe.
8. Selection of a pipe joint is based on what factors?
9. Why must pipes be protected?

CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 3 of 5 Lessons)

3.65 Pipe Installation

3.650 Locating Nearby Utility Lines

Prior to excavating, determine the location of all buried water, sewer, gas, power, telephone and cable TV lines, and storm drains in the work area. Many phone books list an "Underground Service Alert" or "One-Call" phone number which should be called *BEFORE* digging or drilling underground. If these underground lines are damaged during the construction or repairs, it could present serious problems to the community and even result in hazards to the workers. Detailed construction plans showing alignment, grade, and depth specifications for the nearby lines and structures are usually available, and you can ask the utility companies to physically locate their lines. To encourage cooperation, give copies of your preliminary alignment plans for water lines to the other utilities. Ideally, policies and procedures should be established among all public and private agencies involved in installing underground utilities in public right-of-ways (R/W) to coordinate use of the available space. Damage-prevention programs benefit everyone. Agreement on standardized locations for lines will avoid conflicts between utilities and minimize service interruption for utility customers. A specific zone should be assigned for each utility's facilities within the street right-of-way. Standardized zones used by the City of Dallas, Texas, are shown in Figure 3.23 and Figure 3.24 shows another typical layout. After construction, as-built plans must be prepared and maintained and made available to the other utilities as needed.

3.651 Water and Sewer Line Separation

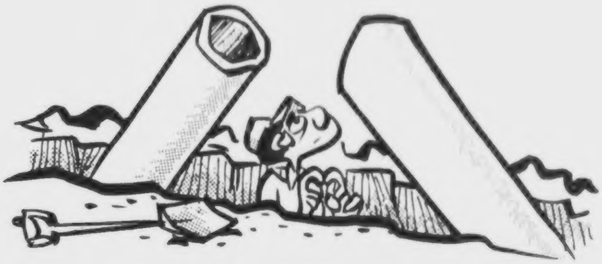
An area of special concern is the separation between the water line being installed and existing nearby sewer lines. Water and sewer lines located close to each other present a hazard if leakage from the sewer line saturates the soil in the vicinity of the water line. If the water main suddenly becomes depressurized and there is no pressure or a negative pressure, contaminants in the saturated soil could be drawn into the water lines. Adequate separation between the two lines, therefore, is needed. Water mains parallel to sanitary sewers should be installed at least 10 feet (3 m) horizontally away from the sewers and at least one foot (0.3 m) higher than any nearby sanitary sewer line. They should never be laid in the same trench with sewer lines. Other wastewater facilities are also of concern. The water main should not be closer than 10 feet (3 m), and preferably 25 feet (7.5 m) horizontally from wastewater leach fields, cesspools, seepage pits, and septic tanks. If local conditions prevent the specific separation, special construction is required. Your local and state health departments may have specific guidelines.

3.652 Storage and Handling

Pipe must be handled very carefully to prevent damage when it is loaded, transported, and unloaded (Figure 3.25). Pipe and other materials received should always be checked for damage upon arrival at the job site and again prior to installation. The best way to check metal pipe is by gently tapping each length of pipe with a hammer. If the pipe does not ring or hum clearly, the pipe is damaged and should be rejected.

Lined and coated pipe must be handled carefully to avoid damaging the protective material. Small-diameter pipe should be unloaded by using skids and ropes. Large-diameter pipe is unloaded by mechanical equipment (fork lifts, cherry pickers or front-end loaders with forks.)

To prevent excessive handling of the pipe, it is desirable to unload pipe at the job site and place it as near as possible to where the pipe is to be used. Normally the pipe is placed along the trench on the side opposite the excavated material.



Be careful to protect pipe that is being stored. Stack it according to the manufacturer's directions and keep it off the ground so that it cannot be contaminated by flooding. Belled pipe should always be stacked with the bells overhanging so that the pipe lies flat. You can protect the ends of the pipes with paper covers. Do not remove the paper covers until the pipe is ready for installation. Plastic pipe stored outside longer than 30 days needs to be protected from the sun by covering it with canvas or other opaque material. All pipe fittings and gasket material should be properly stored so that they will be protected from contamination and kept as clean as possible.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65A What kinds of underground lines should be located prior to excavation?

3.65B When water and sewer lines are not properly separated, what problems could develop?

3.65C How would you check metal pipe for damage upon arrival at the job site and again prior to installation?

3.653 Excavation and Shoring

3.6530 Excavation When excavating a trench for water lines, you may first have to remove some type of surface paving material. Asphalt paving is cut with a wheel type of cutter, a clay spade or a stomper. Concrete can be cut with power saws. The edges of all cuts must be smooth to reduce hazards to workers. All concrete and asphalt debris from the cut paving must be removed before the excavation starts because the debris cannot be used to refill the trench.

The actual excavation may be done by hand or machine. Backhoes, trenching machines, and power shovels are the equipment frequently used for excavation. The backhoe is most often used because it is usually readily available in any needed size, is easily operated, and can also be used to lay the pipe in the trench.

The depth of the trench will depend upon the desired grade line and local conditions. Trenches must be deep enough so that the pipe is protected from freezing, surface traffic, stream or river erosion, and possible future changes in the ground surface elevation. Rock must be excavated to a level six inches (150 mm) below the grade line of the pipe bottom. Water mains need at least 30 inches (750 mm) of cover over the top of the pipe. If water mains are not installed below the frost line, they must be protected to prevent freezing.

Generally, the trench should be no more than one to two feet (0.3 to 0.6 m) wider than the outside diameter of the pipe. This permits proper installation of the pipe and gives the workers enough room to do the work. The trench should be dug only as far ahead of pipe laying as necessary for a smooth operation.

Excavated soil is piled on the side of the trench between the trench and traffic and far enough away so the crew can walk between the trench and the excavated material. The pipe is then laid out on the opposite side of the trench. Excavated rock and unstable material must be hauled away and not used for backfill.

3.6531 Need for Shoring Whenever excavation is necessary for repairs or new construction, shoring (Figures 3.26 and 3.27) may be necessary to protect operators from cave-ins. The need for shoring and shoring requirements depends on many factors, such as, depth of trench, width of trench, type of soil (clay, loam, sand), soil conditions (compaction, moisture) and nearby activities that could cause vibrations.

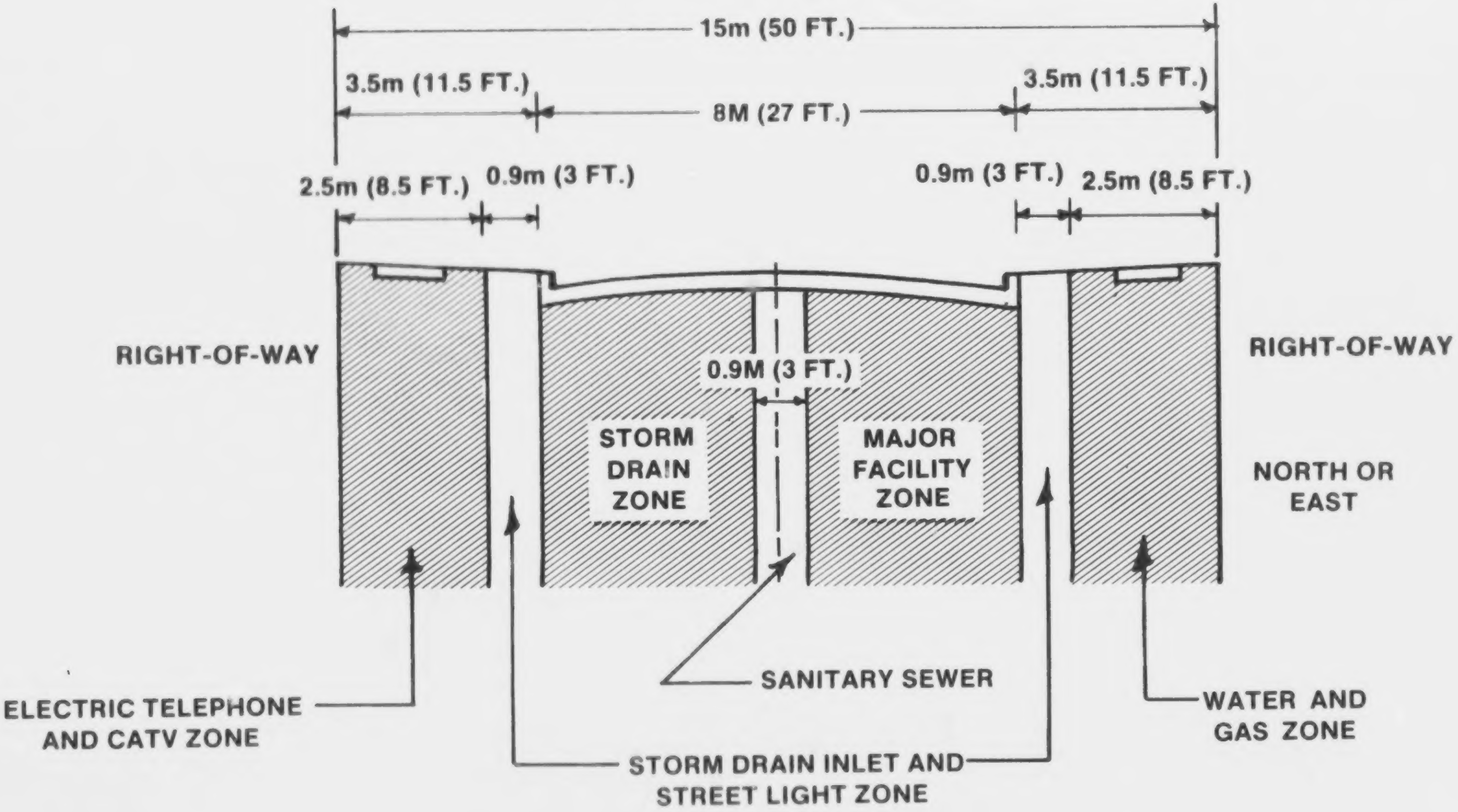

15m (50 FT.)
3.5m (11.5 FT.)
8M (27 FT.)
3.5m (11.5 FT.)
2.5m (8.5 FT.)
0.9m (3 FT.)
0.9m (3 FT.)
2.5m (8.5 FT.)
RIGHT-OF-WAY
RIGHT-OF-WAY
0.9M (3 FT.)
STORM DRAIN ZONE
MAJOR FACILITY ZONE
NORTH OR EAST
SANITARY SEWER
ELECTRIC TELEPHONE AND CATV ZONE
WATER AND GAS ZONE
STORM DRAIN INLET AND STREET LIGHT ZONE

Fig. 3.23 Typical utility locatios in a minor street

(Adapted from Cowgill, J.E., "Coordinating Utility Location: A Defense Against Distribution System Damage," JAWWA, Vol. 73, No. 2, p. 87, February, 1981.

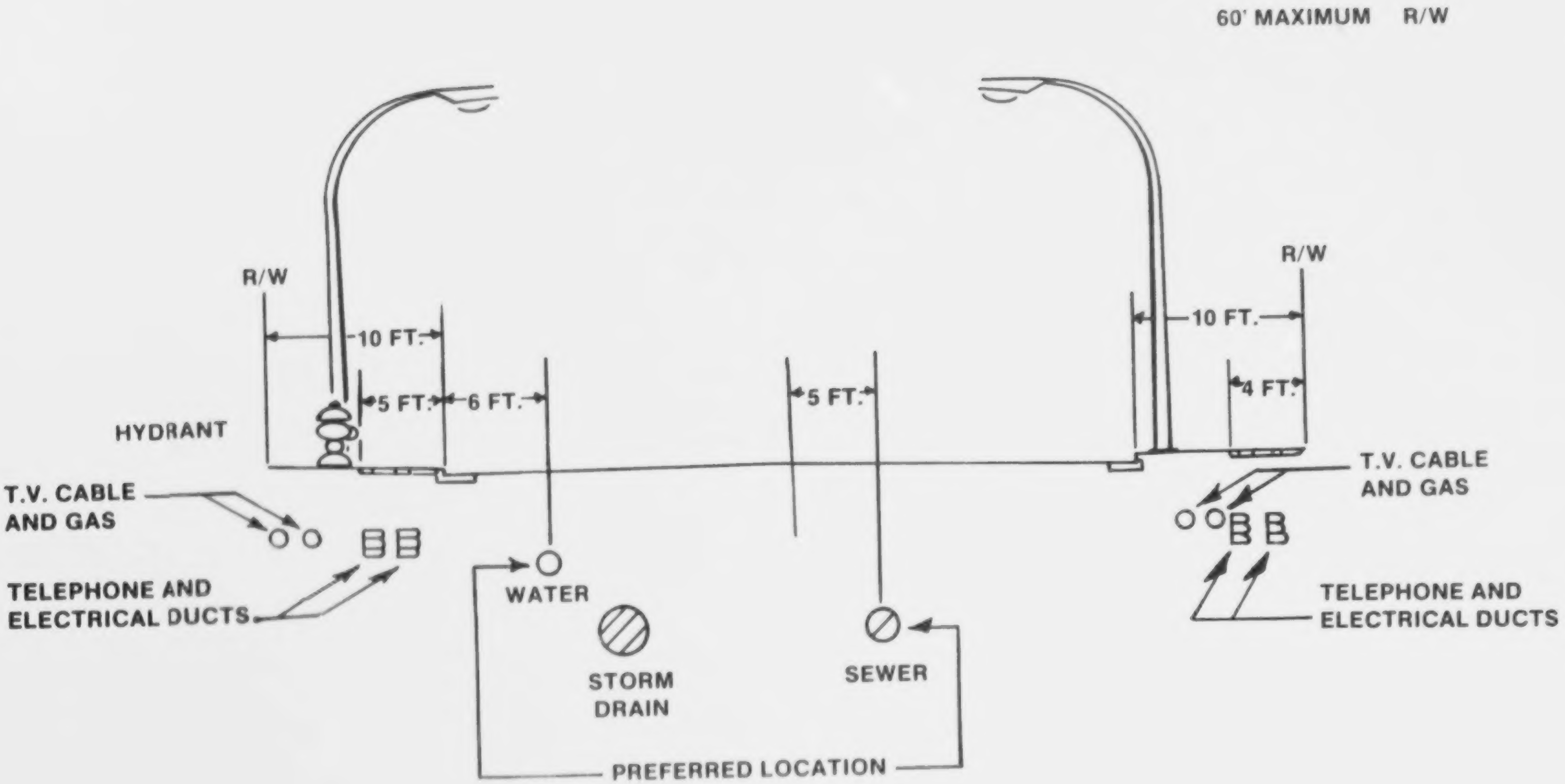
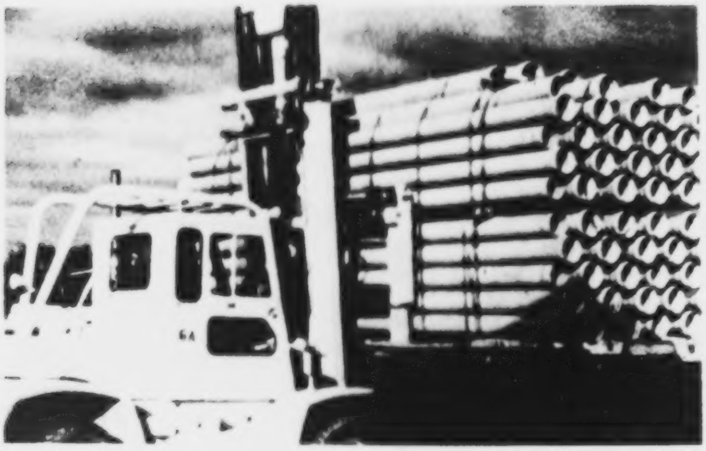
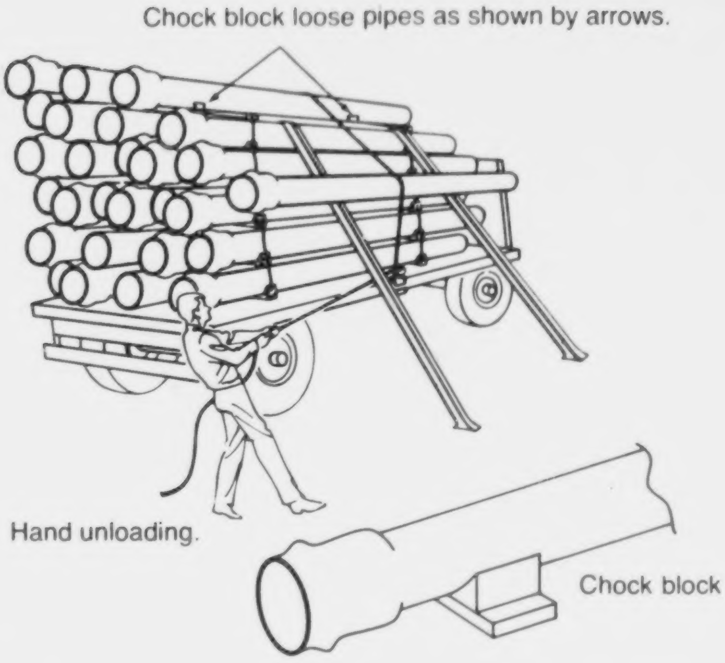

60' MAXIMUM R/W
R/W
R/W
10 FT.
10 FT.
5 FT.
6 FT.
5 FT.
4 FT.
HYDRANT
T.V. CABLE AND GAS
T.V. CABLE AND GAS
TELEPHONE AND ELECTRICAL DUCTS
TELEPHONE AND ELECTRICAL DUCTS
WATER
STORM DRAIN
SEWER
PREFERRED LOCATION

Fig. 3.24 Typical utility locations

(Adapted from *MODEL STANDARD LOCATIONS FOR UTILITIES IN PUBLIC RIGHTS OF WAY*, prepared by Uniform Ordinances and Practices Committee of the Southern California Chapter, American Public Works Association, 1975, Second Edition.



Fork lift unloading (preferred)

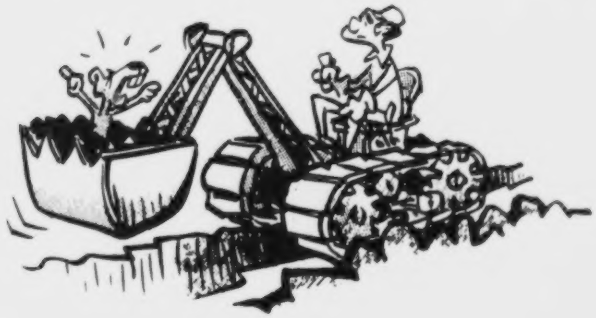

Chock block loose pipes as shown by arrows.
Hand unloading.
Chock block

Hand unloading

Fig. 3.25 Unloading pipe

(Permission of Johns-Manvile Corporation, a Subsidiary of Manville Corporation)

Another consideration when determining shoring requirements is the length of time you expect the excavation to be open. If an excavation is going to be open for an extended period, you would want heavier bracing to provide additional protection against vibrations from traffic and rains that could cause flooding.



Shoring requirements are dictated by laws and codes and are strictly enforced by the regulatory agencies. Lack of shoring or shoring failure are the major causes of underground construction deaths. For example, seven people died and there were 67 lost-time injuries related to construction shoring problems in California during one year. How can we prevent these accidents? First learn the shoring laws and codes, types of shoring, proper use, and then *APPLY THIS KNOWLEDGE*. Also, develop a safety program and organize an approved OSHA (Occupational Safety and Health Act) shoring class for operators and workers. The Williams-Steiger Occupational Safety and Health Act (OSHA) of 1970 contains shoring regulations, and they are strictly enforced. Penalties for violating the regulations include warnings, fines and even prison sentences for flagrant or repeated violations. Contact your local safety office for all regulations pertaining to any excavations done by you or your crews.

3.6532 Typical Shoring Requirements Typical shoring requirements include:

1. Shoring systems in trenches shall consist of uprights held rigidly opposite each other against the trench walls by jacks or horizontal cross members (cross braces) and, if required, longitudinal members (stringers) as specified below.
2. Uprights shall not exceed 15 degrees from the vertical. Uprights in trenches over 10 feet (3 m) deep shall be not less than 3-inch by 8-inch material, and shall be at least 2-inch by 8-inch material in trenches less than 10 feet deep.

   Uprights shall extend from above the top of the trench to as near the bottom as permitted by the material being installed, but not more than two feet (0.6 m) from the bottom.
3. Cross braces shall consist of steel screw-type trench jacks with a foot or base plate on each end of pipe or timbers placed horizontally and bearing firmly against uprights or stringers.

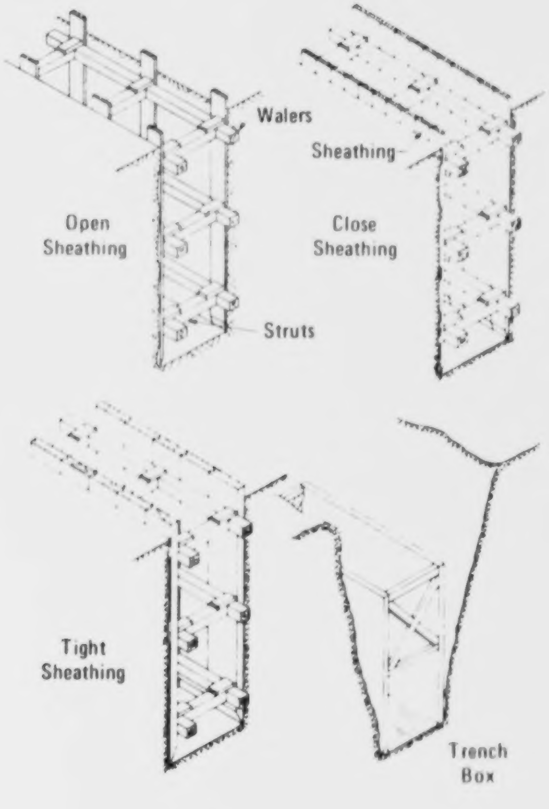
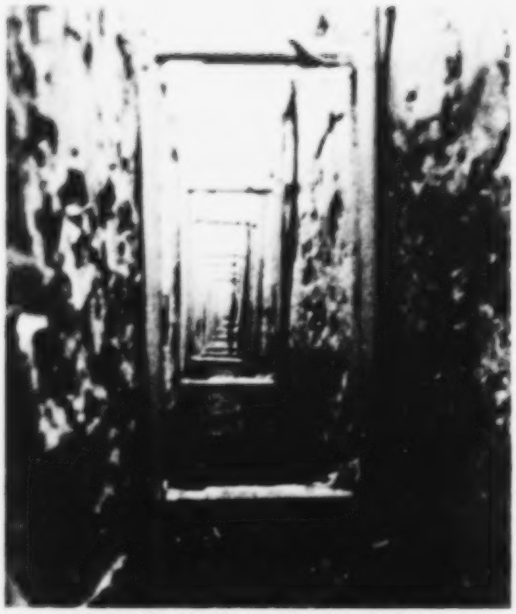
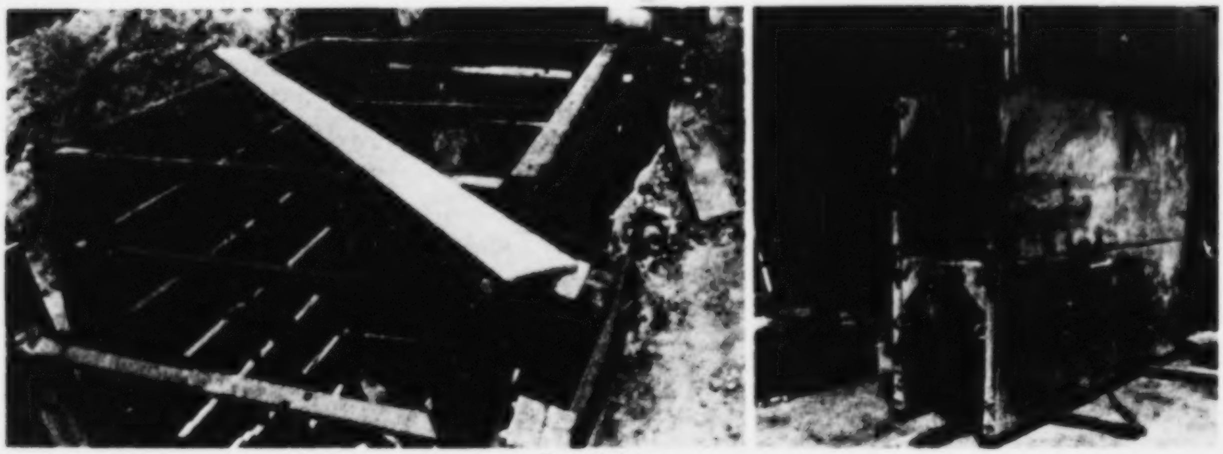


Fig. 3.26 Types of shoring

(Reprinted from CONCRETE PIPE HANDBOOK, by permission
Copyright 1981, the American Concrete Pipe Association)



Hydraulic aluminum shoring devices



Trench boxes

Fig. 3.27 Shoring equipment

(Permission of Trench Shoring Company)

4. The minimum number of horizontal cross braces, either screw jacks or timbers, required for each pair of uprights shall be determined by the number of 4-foot (1.2 m) zones or segments into which the depth of trench may be divided. One horizontal cross brace shall be required for each of these zones, but in no case shall there be less than two cross braces or jacks. Trenches, the depths of which cannot be divided equally into these standard 4-foot (1.2 m) zones or segments, shall have an extra horizontal cross brace supplied for the short remaining zone, if such zone is greater than two feet. In no case, however, shall the vertical spacing of horizontal cross braces be spaced greater than 5 feet (1.5 m) center to center. Minor temporary shifting of horizontal cross bracing will be permitted, when neceesary, for the lowering of materials into place. Be sure no one is allowed in the trench while the cross braces are temporarily shifted or moved. If the diameter of a pipe is greater than four feet, the lower cross braces require alternate considerations.
5. The dimensions and spacing of the elements of the shoring system shall be governed by the depth of the trench, type of soil encountered, and other special conditions of the site.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65D How is the depth of a trench determined?

3.65E Shoring requirements depend on what factors?

3.65F What is the number one cause of cave-in deaths?

3.65G What are the components of a typical trench shoring system?

3.65H Uprights must extend how close to bottom of trench?

3.6533 Responsibility Someone must be on the job site and in charge at all times (a foreman or a crew leader). This person not only accepts responsibility, but is authorized to change any predetermined shoring system when soil conditions change. Material handling, traffic pattern changes, public relations, repair work excavation, backfill and compaction are directed by the person in charge. Some of these jobs will have to be delegated, of course, or they won't be done effectively.

TAILGATE SAFETY MEETINGS[23] and preconstruction meetings are very important. Everyone on the job site must know exactly what to do and what the crew is expected to accomplish.

3.6534 Placing of Spoil While digging trenches less than five feet (1.5 m) in depth, the spoil (excavated material) should be placed two feet (0.6 m) or more back from the edge of the trench. For trenches deeper than five feet (1.5 m), place the spoil four feet (1.2 m) or more back from the edge of the trench. Try to keep the area between the trench and the spoil area clear of loose material. If not kept clear, rocks, tools and pipe could be knocked into the excavation, or someone could trip on the equipment and fall into the trench. Keeping the area clear is not only good for the safety of operators, but reduces the chances of damage to new pipe or other conduits and utilities (which could cause thousands of dollars worth of damage). Also, keeping spoil away from the edge of the trench tends to reduce the load on the side walls, thus reducing the loads on the sheeting, uprights, stringers and cross bracing.

3.6535 Typical Shoring Regulations

1. Operator Safety

All trenches four feet (1.2 m) in depth and deeper must be effectively shored to protect operators against the hazard of moving ground. Trenches less than four feet (1.2 m) in depth also must be shored when examination indicates hazardous ground movement may be expected.

Special provisions must be made to prevent injury to operators while they install shoring. The use of special devices such as long handled jacks will allow upper cross braces to be placed from the ground surface before operators enter the trench. At those points in deep trenches requiring additional braces, operators should then progress downward, protected by cross braces that have already been set firmly in place. Reverse this procedure when you remove the shoring.

2. Soil Conditions and Trench Location

The type of shoring you'll need depends on the soil conditions and the location of the trench. You cannot shore an excavation alongside a railroad track the same way as one in an open area because of vibrations created by passing trains. When the decision is made on the type of shoring to use, remember that soil conditions change and an alternate shoring system should be readily available so that little work time will be lost if a change must be made.

3. Sloping Excavation Walls

Instead of installing a shoring system, the sides or walls of an excavation may be sloped if this method is considered more economical and the job can be done safely. If you decide to slope the walls of an excavation that would otherwise need shoring, excavate the side walls on a slope of ¾ foot horizontal to one foot vertical except where the instability of material requires a slope of greater than ¾ : 1 (¾ vertical to 1 horizontal).

4. Access to Construction Work Area

Convenient and safe means must be provided for operators to enter and leave the excavated area. Use a standard stairway, ladder or ramp securely fastened in place at suitably guarded or protected locations where people are working. Ladders usually are less than 100 feet (30 m) apart.

---

[23] *Tailgate Safety Meeting. The term TAILGATE comes from safety meetings regularly held by the construction industry around the tailgate of a truck.*

5. Pedestrian Safety

When working near curbs and sidewalks, keep a pedestrian way open on the sidewalks. If this area becomes covered with material and equipment, the pedestrians will be in the work area or walking across someone's yard. Neither one of these situations is acceptable. If necessary, erect barriers to keep pedestrians and children in safe, permissible areas. Be especially careful if children are playing or watching near the job site.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65I What authority does the person supervising excavation work have?

3.65J Where should spoils or excavated material be placed in relation to the trench?

3.65K All trenches deeper than _____ feet must be shored.

3.65L How can operators be protected if shoring is not practical?

3.65M Why must a walkway be provided for pedestrians?

3.6536 Types of Shores There are several types of shores that have been tested and approved by OSHA. Each type of shoring has its good and bad points. Selection of types of shoring depends largely on soil conditions in your area.

1. Hydraulic Shores (Figure 3.28)

Hydraulic shores are used frequently due to their ease of installation and removal. They are usually not used on jobs when they will have to be left installed in one segment of trench for longer than five days. This is due to the possibility of the hydraulic pressure bleeding off during a longer period of installation.

2. Screw Jacks (Figure 3.29)

Screw jacks are time consuming to install and usually are not used on large production jobs. They are inexpensive, however, and for minor repairs in smaller excavations, they are more practical than other types of shores. Screw jacks must be installed from the top of the trench down, and those who have used them know this is a slow process. Screw jacks are made of iron and come in two pieces. They are available with a 1½ or 2-inch (38 to 50 mm) threaded shaft and wing nut that is used for adjustment to fit trench width. One end of the shaft is plain and the other has a ball-socket for a shoe that pushes against the shoring. The screw length on the 1½ inch (38 mm) shaft varies from 10 to 18 inches (250 to 450 mm). The 2-inch (50 mm) shaft has a screw length of 18 inches (450 mm) only.

3. Air Shores (Figure 3.30)

Air shores are pneumatic shoring cross braces. They are not equipped with rails like hydraulic shores. They function like screw jacks and are used only as the cross brace which can be rapidly set to hold shoring members in place.

4. Solid Sheeting (Figure 3.31)

Occasionally it is necessary to excavate in materials that will not stand in a vertical position and where it is not practical to slope the trench. Under these circumstances, you must use a solid-sheeting method. Fully dimensional rough cut timbers are used. Minimum sizes are 2 x 8 inch (50 x 200 mm) rough timbers for trenches up to 8 feet (2.4 m) deep and 3 x 8 inch (75 x 200 mm) rough timber for trenches over 8 feet (2.4 m) deep. Metal plates can be used as solid sheeting if they are properly engineered.

The horizontal shoring members are generally referred to as "stringers" or "walers." When purchasing shoring material, buy the square 6 x 6 rough timber, or the 8 x 8 rough timber because finished dimensional timber is smaller and not as strong. Hydraulic shores, air shores or screw jacks can be used as cross braces.

5. Cylinder Shoring (Figure 3.32)

Cylinder shoring can be made from ¼-inch or 5/16-inch (6 mm or 8 mm) thick steel plates that are four feet (1.2 m) wide. These sheets are rolled into a cylinder with a four-foot (1.2 m) inside diameter and four feet (1.2 m) in height. The top and bottom of each cylinder is reinforced with a welded angle iron rolled to fit the cylinders. Each cylinder section weighs either 550 (1¼-inch (6 mm) plate) or 675 (5/16-inch (8 mm) plate) pounds (250 or 305 kg). This weight usually limits the use of cylinder shoring to street locations or areas where cranes or hydro lifts can be used to position the cylinders. Cylinders four feet (1.2 m) high and four feet (1.2 m) in diameter are easy to transport and handle, but are confining on large jobs.

6. Shield Shoring (Figure 3.33)

Shield shoring is used during excavation and installation of various types of water mains in areas and soil conditions that present a combination of problems. Shield shoring consists of a rectangular box that must be open on the top and bottom and usually the ends are open too. Size of shield depends on the size of water line being installed and the space needed to install the pipe. Shields can vary in width from 30 inches (0.75 m) to 10 feet (3 m) and in length from 20 to 30 feet (6 to 9 m).

3.6537 Shoring Summary This section has identified the common types of shores and their uses. Selection of shores depends on several factors and the job you are trying to accomplish.

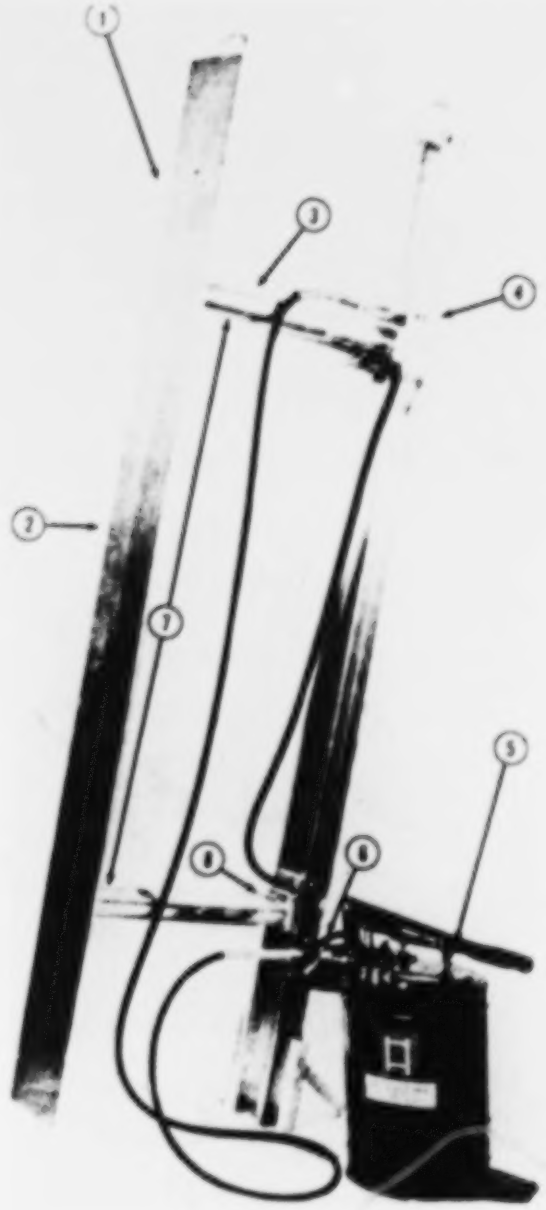
PROTECT YOUR OPERATORS AT ALL COST.
Attend all trench safety lectures
and seminars. Contact your own safety
council and see what information is
available and what is required. Be sure
that everyone complies with all regulations.
ALL TRENCHES AND EXCAVATIONS ARE
UNSAFE UNTIL PROPERLY SHORED,
USED AND BACKFILLED.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65N List the different types of common shores.

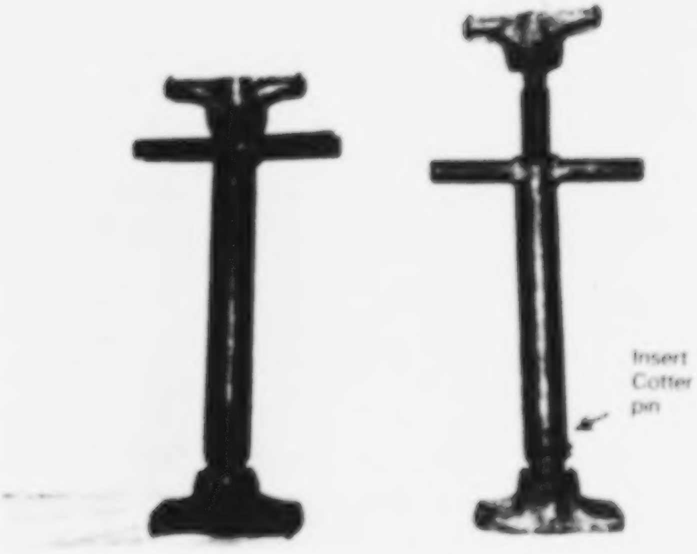
3.65O What should be your major concern during a shoring operation?



1. Aluminum alloy material
2. Flanged siderail
3. Hydraulic cylinder
4. Offset pins connecting siderails and hydraulic cylinders
5. Pump
6. Pressure gage
7. 4-foot cylinder spacing
8. Cylinder pad

Fig. 3.28 Aluminum hydraulic cylinder

(Courtesy of SPEED-SHORE)


Insert
Cotter
pin

Screw jacks

Screw jacks with timber uprights

WARNING — Never use jacks for access ladders. Always use a ladder.

Fig. 3.29 Screw jacks

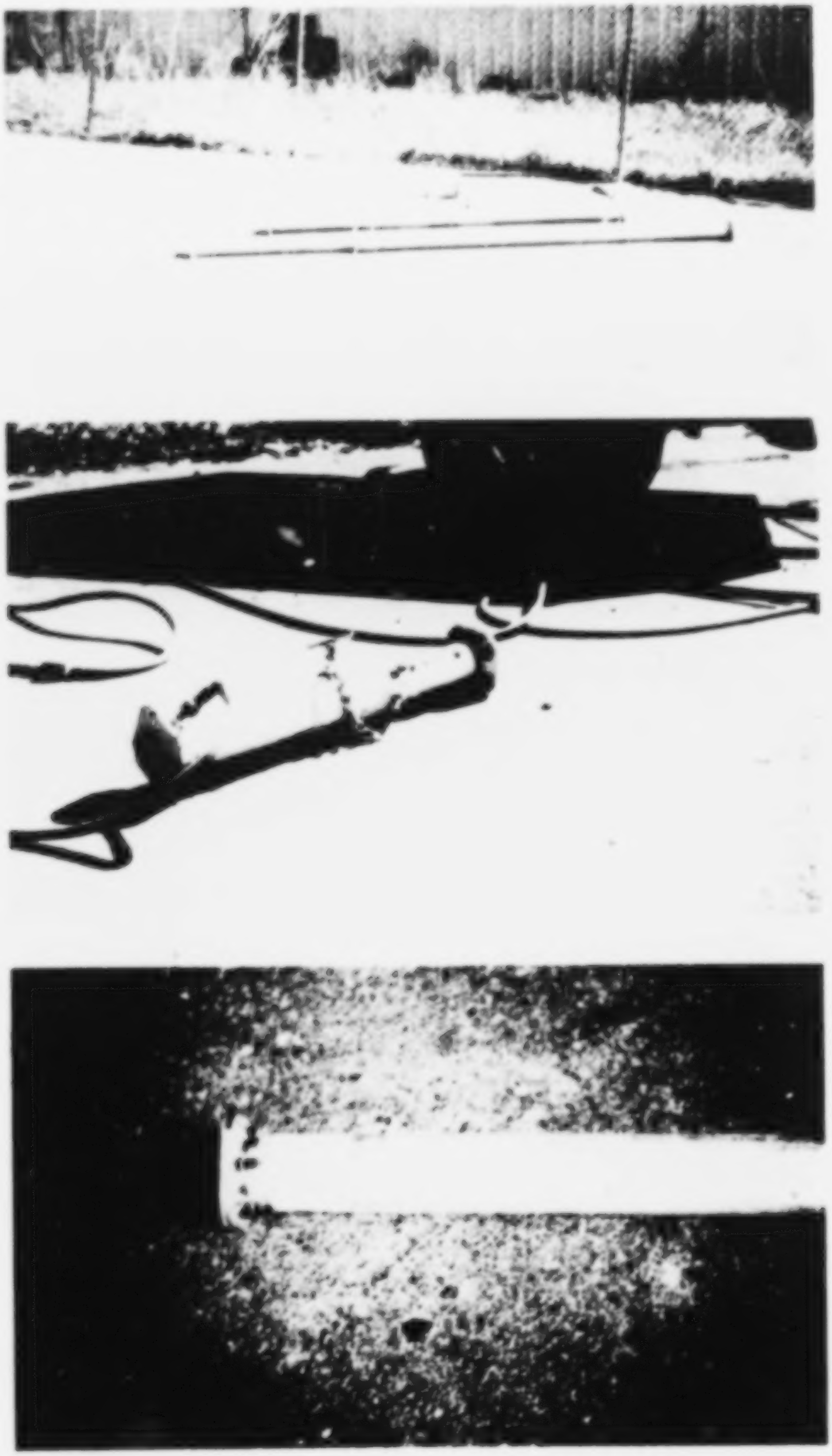


Fig. 3.30 Air shores

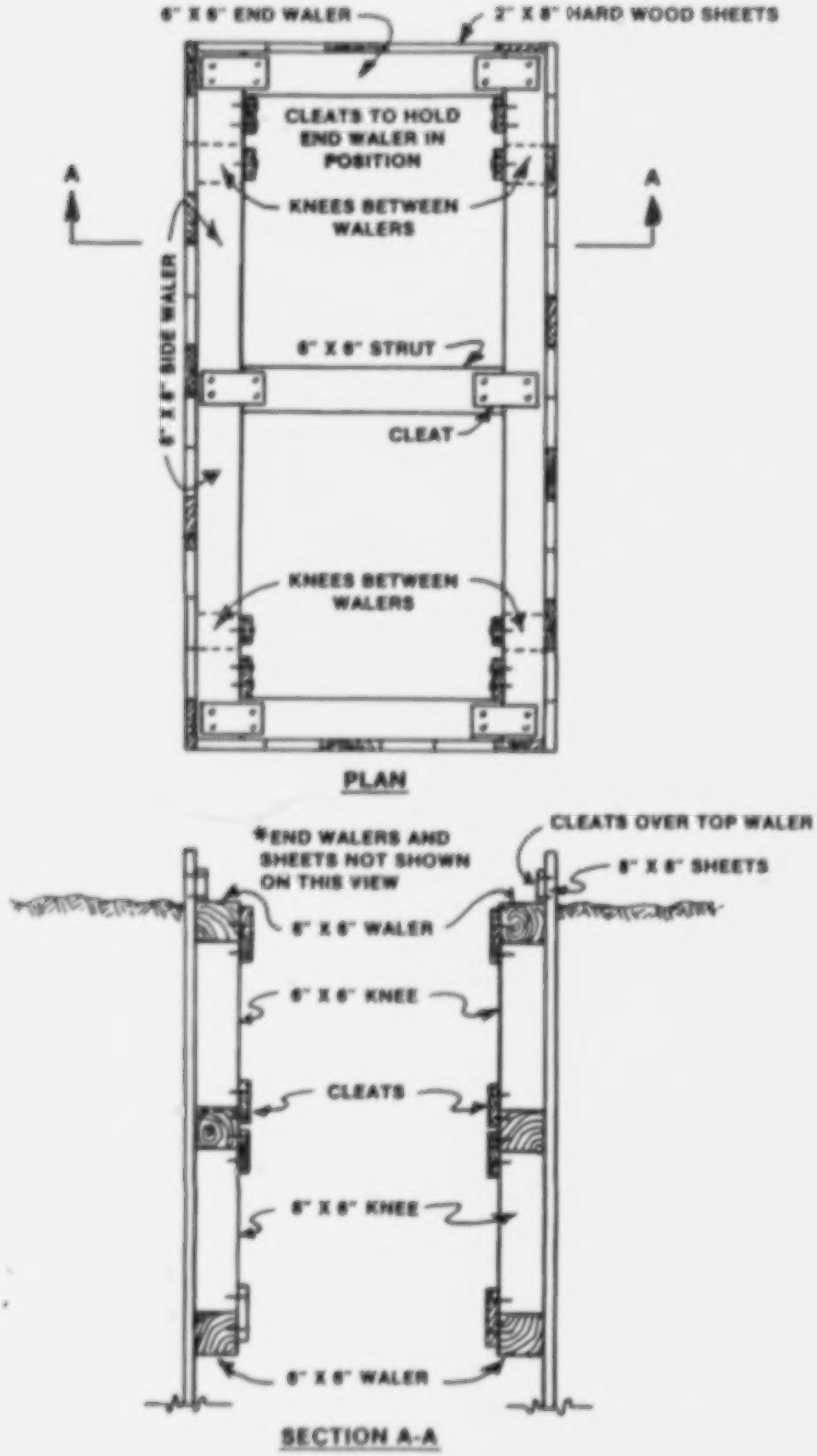
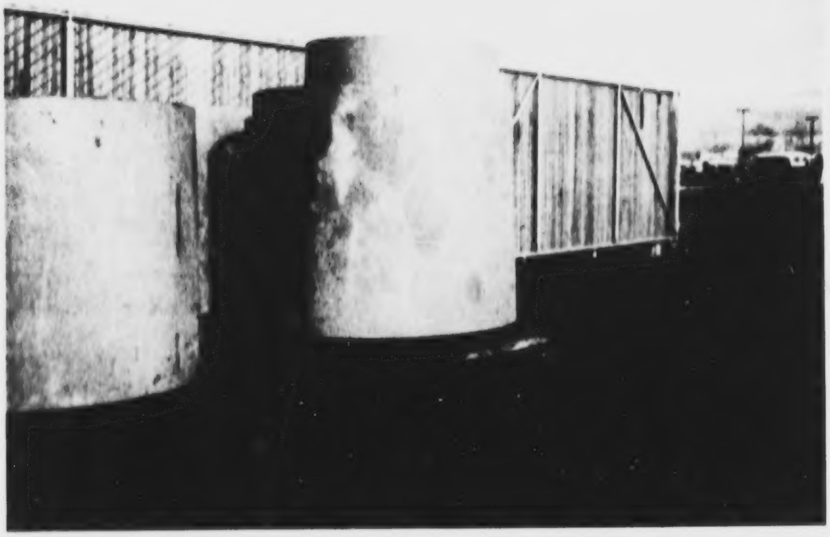
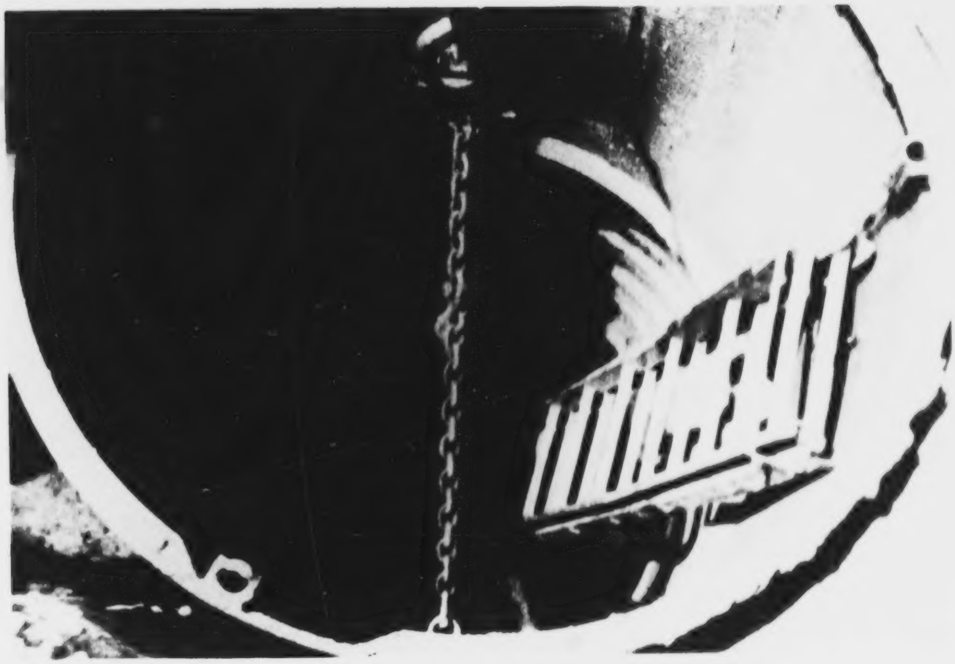

8" X 8" END WALER
2" X 8" HARD WOOD SHEETS
CLEATS TO HOLD END WALER IN POSITION
A
A
KNEES BETWEEN WALERS
8" X 8" SIDE WALER
8" X 8" STRUT
CLEAT
KNEES BETWEEN WALERS
PLAN
*END WALERS AND SHEETS NOT SHOWN ON THIS VIEW
CLEATS OVER TOP WALER
8" X 8" SHEETS
8" X 8" WALER
8" X 8" KNEE
CLEATS
8" X 8" KNEE
8" X 8" WALER
SECTION A-A

Fig. 3.31 Solid sheeting



Cylinder shoring



Ladder inside cylinder

Fig. 3.32 Cylinder shoring

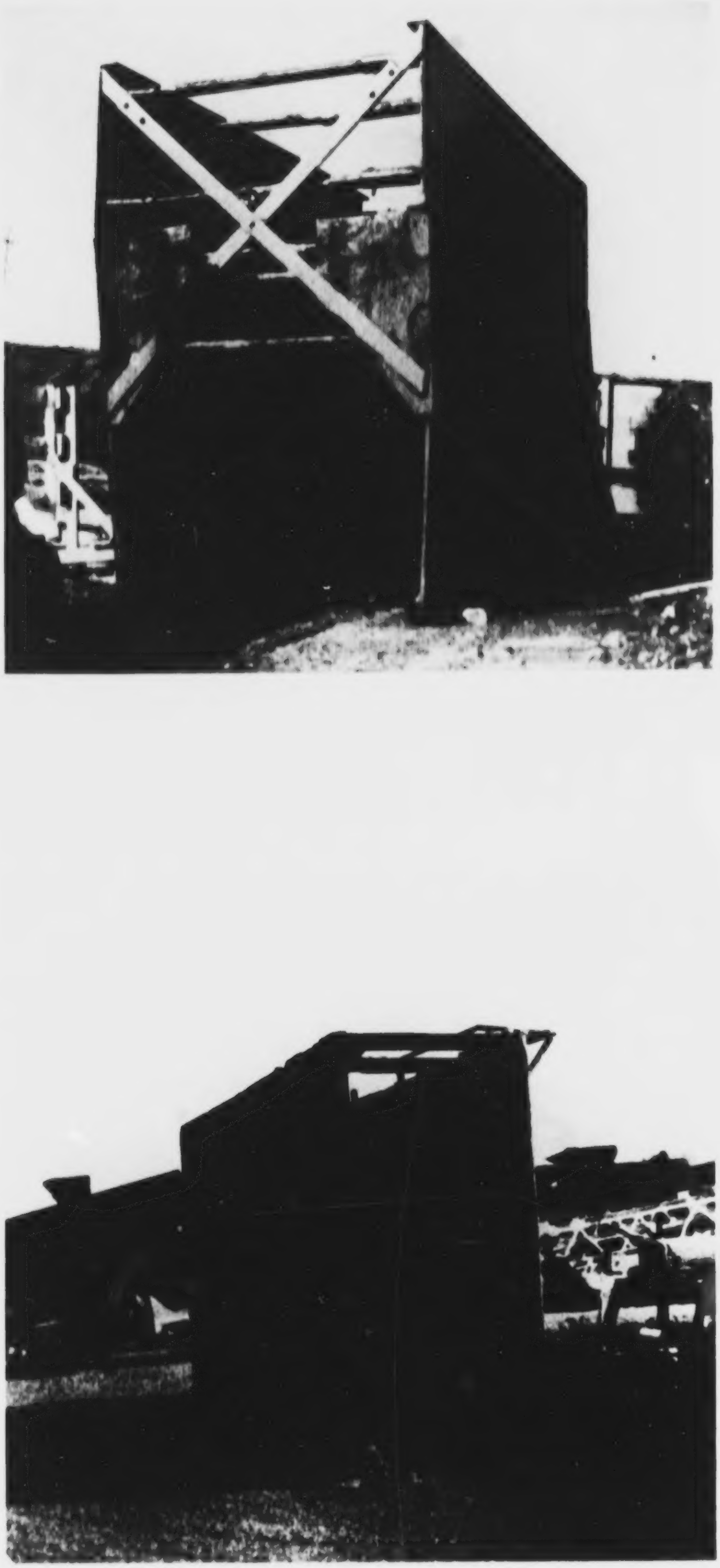


Fig. 3.33 Shield shoring

3.6538 **Bedding** Bedding is the material placed in the bottom of the trench to support the pipe. The trench bottom is often brought back up to grade with sand or soil to provide a suitable bedding. However, with the proper soil, pipe could be laid directly on the trench bottom. Special care must be taken to assure that couplings will not rest on or settle down to the original trench bottom and also that the pipe is provided with even bedding for its entire length (Figure 6.33).

3.654 *Pipe Laying and Jointing*

Laying the pipe out for installation is called stringing. Small diameter pipe is laid by hand and should be strung along the trench. When belled pipe is used, point the bells in the direction that the work is proceeding, except when the pipe is being laid downhill then the bell should face uphill.

Never allow pipes to drop into the trench: carefully lower them into position. Pipes up to 12 inches (300 mm) in diameter can be lowered into the trench manually with two ropes, one tied to each end of the pipe (Figure 6.34). Larger pipe must be handled with power equipment. Cable slings may be used to lower pipe into trenches (Figure 6.35). Always move pipe very carefully so it will not be damaged. Special precautions must be taken to protect any interior and exterior pipe coatings.

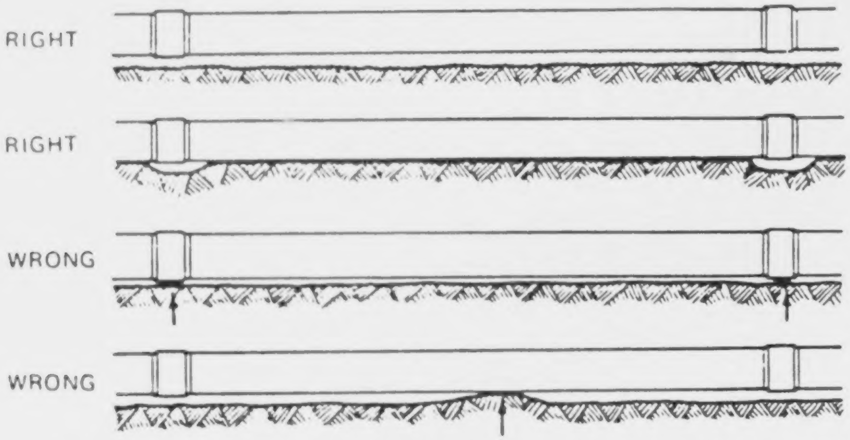
Before placing pipe in the trench, inspect the inside and outside of each pipe. Remove all debris found inside the pipe. If there is any question about the cleanliness of the pipe, brush the inside to remove any loose dirt and then swab it with a strong hypochlorite solution. Keep all gaskets clean and dry. When work is not in progress and at night, the open ends of the installed pipe should be plugged tightly.

Before you begin jointing, carefully clean the ends of the pipes and the joint materials and smooth out any rough edges. Each type of pipe material requires special jointing procedures and all joints should be installed carefully in accordance with these procedures. One feature is common to most jointing methods: a distinctive sound is heard when the pipe is correctly pushed home. When rubber gaskets are used, check the completed joint with a feeler gage to make sure that there is proper seating. Only recommended lubricants are to be used because some lubricants could ruin gaskets or support bacterial growth.

The same methods used for jointing in straight pipe are also used for installing valves, fittings and fire hydrants which are connected as the pipeline is laid.

3.655 Thrust Blocks (Figure 3.37)

Thrust forces in water mains are created where the pipeline changes direction or size, at dead ends, and when valves and hydrants are quickly closed. Thrust blocks are used at these points to prevent damage caused by internal pressures and to keep the pipeline intact. All tees, bends, caps, plugs, hydrants, or other fittings that change the direction of flow or stop the flow should be restrained or blocked to prevent leakage or separation of the joints. Thrust blocks made of concrete and steel reinforcement rods are often used. Wood or any other material that deteriorates is not acceptable. The concrete should be in contact only with the fitting, not with the pipe itself or the joint. Thrust blocks should rest against undisturbed solid soil for their required bearing area. The size of the thrust blocks depends on the water pressure, the size of the pipeline, the type of fitting in need of protection and the type and



COUPLINGS–NEVER ALLOW COUPLINGS TO REST ON, OR TO SETTLE DOWN TO, ORIGINAL TRENCH BOTTOM

PIPE–MAKE CERTAIN THAT PIPE BARREL IS GIVEN AN EVEN BEARING FOR ITS FULL LENGTH

Fig. 3.34 Pipe bedding

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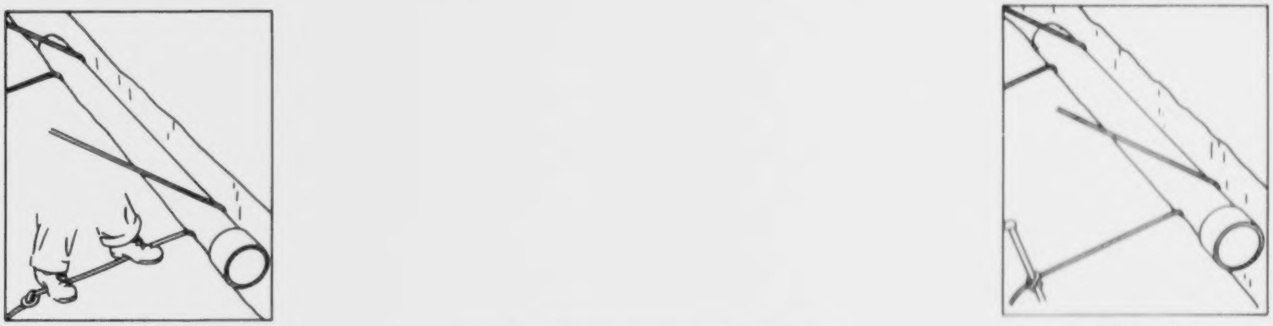


Method A

Use of ropes to lower pipe into trench

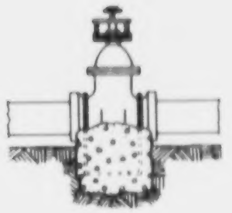
Method B

Fig. 3.35 Lowering pipe into trench

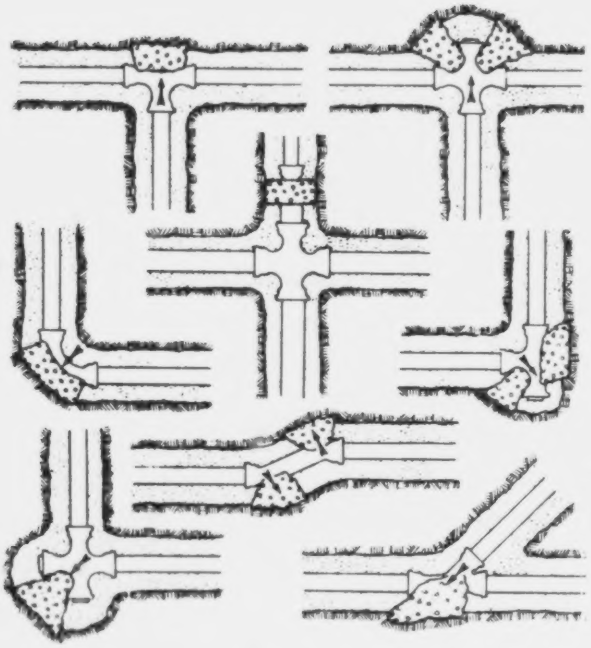
(Permission of the Johns-Manville Corporation, a Subsidiary of the Manville Corporation)

Fig. 3.36 Use of cable sling to lower pipe into trench

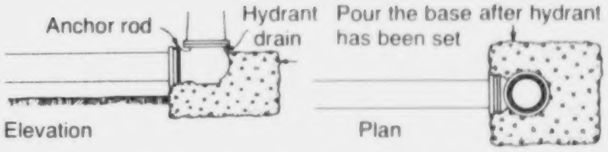
(Permission of the Ductile Iron Pipe Research Association)



Valves

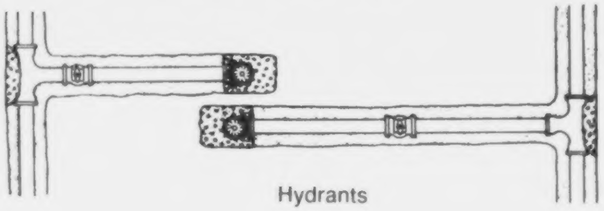


Fittings



This type of hydrant foundation acts as a thrust block, as an anchorage against frost-heave and eliminates washouts from waste-water drain.

When the fittings are used in a hydrant run-out, a single length can be used to connect two fittings.



Hydrants

Fig. 3.37 Thrust blocks

(Permission of the Johns-Manville Corporation, a Subsidiary of the Manville Corporation)

character of soil that backs up the thrust block. Pipelines should not be pressure tested until the concrete in the thrust blocks has had time to set properly (at least five days).

3.656 Backfilling

After the pipe has been laid, jointed, and thrust blocks installed, the excavation is manually backfilled with select material. Compaction may be required depending on the trench conditions. Compaction around the pipe and above it, when required, is done gradually in stages. The first layer of backfill is compacted up to the horizontal center line of the pipe. The backfill material must contain enough moisture for full compaction and consolidation under and on both sides of the pipe so that the pipe is supported without any hollow spaces in the soil. The purpose of tamping the soil around the pipe is to provide uniform support and bearing (Figure 3.38).

Frequently, the pipe is backfilled and tamped except at the joints which are left exposed until the pipe has been tested under water pressure. Following the water pressure test, the backfilling can be completed. Tamping of the backfill above the pipe can be done by hand or machine, or by applying water (jetting), depending on local conditions and convenience. If the trench is in a road, the completed backfill must meet the compaction requirements of the appropriate local agency.

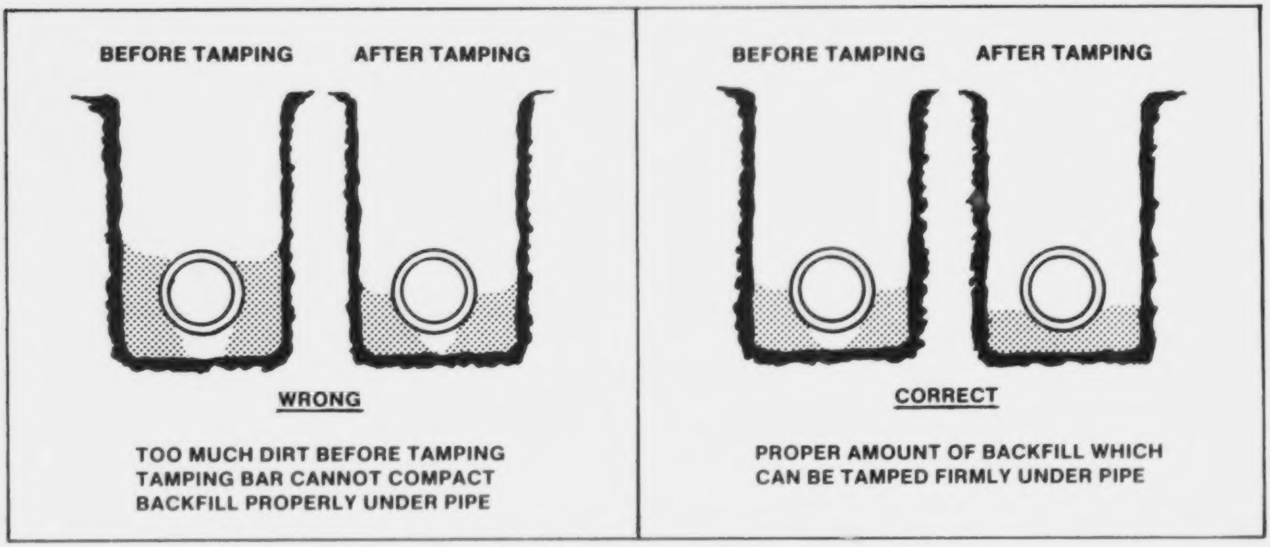

BEFORE TAMPING
AFTER TAMPING
WRONG
TOO MUCH DIRT BEFORE TAMPING
TAMPING BAR CANNOT COMPACT
BACKFILL PROPERLY UNDER PIPE
BEFORE TAMPING
AFTER TAMPING
CORRECT
PROPER AMOUNT OF BACKFILL WHICH
CAN BE TAMPED FIRMLY UNDER PIPE

Fig. 3.38 Tamping procedures

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QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65P What precautions should be taken when laying pipe on bedding?

3.65Q When laying pipe with a bell, the bell should point in what direction?

3.65R How should pipes be prepared before they are joined together?

3.65S Where should thrust blocks be installed?

3.65T How deep is the first layer of backfill?

3.657 Pressure and Leakage Tests

Leakage tests are done after the trench has been partially backfilled. As mentioned, the joints are often left uncovered until after the test is completed. Each valved section of the main is filled slowly with water, with air in the pipe being released through *CORPORATION STOPS*[24] and hydrants. All air must be removed before the pressure testing starts. After the pipe is full, it should sit idle for at least 24 hours before the test starts. Then, the pressure is brought up to a level at least 50 percent higher than the normal expected operating pressure, or 150 psi (1034 kPa or 10.5 kg/sq cm), whichever is larger, and maintained for at least four hours. Any loss of pressure would indicate leakage. The amount of water needed to refill the pipe is measured. Leakage can also be determined by examination of the trench for visible leaks or by the use of a meter to detect any pipe flow. If any joints do show leakage, they are checked and adjusted or repaired. However, some leakage is to be expected, and the AWWA has specifications for allowable leakage for different types of pipe (Table 3.1). During and after the test the trench is also observed to determine if there is any pipe movement.

TABLE 3.1 ALLOWABLE LEAKAGE FROM PIPES[a]

Pipe Material	Pipe Length, ft	Test Pressure, psi	Allowable Leakage GPD/mi-in[b]
Asbestos-Cement	13	150	30
Ductile Iron	18	150	23.3[c]
Plastic	—	150	1.45[d] 1.88[e]

[a] AWWA Standards for each type of pipe material.
[b] Allowable leakage in gallons per day per mile of pipe per inch of diameter.
[c] Allowable leakage for mechanical and push-on joints.
[d] Allowable leakage is 1.45 gallons per hour for each 100 joints for six-inch (150 mm) pipe.
[e] Allowable leakage is 1.88 gallons per hour for each 100 joints for eight-inch (200 mm) pipe.

FORMULAS

Do not fill a pipe with water too fast because tablets for disinfection may be washed off the top of the pipe. Also excessive velocities could cause pipe movements when the water flows around fittings which could cause leaks. Pipes should not be filled greater than at a rate of one foot of pipe length per second. To determine the maximum flow meter reading in gallons per minute, use the formulas shown below.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

$$\text{Flow, cu ft/sec} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

and

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

---

[24] *Corporation Stop. A water service shutoff valve located at a street water main. This valve cannot be operated from the ground surface because it is buried and there is no valve box. Also called a CORPORATION COCK.*

The first formula calculates the area of a pipe in square feet when the diameter is given in inches. The second formula gives us the flow in cubic feet per second by multiplying the area in square feet times the velocity in feet per second. The last formula converts the flow from cubic feet per second to gallons per minute by converting the cubic feet to gallons and the seconds to minutes.

Leak tests on asbestos-cement and ductile iron pipe report the results in terms of gallons of water leaked per day per miles of pipe length and inches of pipe diameter.

$$\text{Actual Leakage, GPD/mi-in} = \frac{\text{Leak Rate, GPD}}{\text{(Length, mi)(Diameter, in)}}$$

Leak tests on plastic pipe are reported in terms of gallons per hour for each 100 joints of pipe. Therefore, if the test section had 54 joints we would have 0.54 — 100 joints of pipe. This means we had a little over half (0.54) of 100 joints.

$$\text{Actual Leakage, GPH/100 joints} = \frac{\text{Leak Rate, gal/hr}}{\text{Number of 100 joints}}$$

EXAMPLE 4

A 500-foot long section of a 12-inch diameter water main is being filled with water for a leakage test. If the pipe is filled at a flow rate of less than one foot of pipe length per second, what should be the maximum flow meter reading in gallons per minute for filling the pipe?

Known		**Unknown**
Length, ft	= 500 ft	Flow, GPM
Diameter, in	= 12 in	
Fill Rate, ft/second	= 1 ft pipe length per second	

1. Calculate the maximum allowable flow in cubic feet per second.

Flow, cu ft/sec = (0.785)(Diameter, ft)^2(Fill Rate, ft/sec)

= (0.785)(1 ft)^2([illegible] ft/sec)

= 0.785 cu ft/sec

2. Determine the maximum flow meter reading in gallons per minute.

Flow, GPM = (Flow, cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= (0.785 cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= 352 GPM

Do not allow the flow through the meter to exceed 350 GPM.

EXAMPLE 5

The normal expected operating pressure of a pipe is 120 psi. At what pressure should the pipe be tested if the test pressure is 50 percent higher than the normal expected operating pressure or 150 psi, whichever is larger?

Known		**Unknown**
Normal Pressure, psi	= 120 psi	Test Pressure, psi
Test Pressure, psi	= Normal + 50%	
or	= 150 psi	

whichever is larger.

1. Calculate the test pressure.

$$\text{Test Pressure, psi} = \text{Normal Pressure, psi} + \frac{\text{50\% (Normal Pressure, psi)}}{100\%}$$

$$= 120\text{ psi} + \frac{(50\%)(120\text{ psi})}{100\%}$$

$$= 120\text{ psi} + 60\text{ psi}$$

$$= 180\text{ psi}$$

Use a test pressure of 180 psi because this is greater than 150 psi.

EXAMPLE 6

A 24-hour leak test is performed on 1,000 feet of 12-inch diameter asbestos-cement pipe with a test pressure of 150 psi. The pipes are 13 feet long. According to Table 3.1, the allowable leakage is 30 gallons per day per mile of pipe per inch of diameter. During the 24-hour test period, 20 gallons of water were added to maintian the 150 psi pressure. Did the pipe pass the leak test?

Known		**Unknown**
Test Duration, hr	= 24 hr	1. Actual Leakage GPD/mi-in
or	= 1 day	
Pipe Length, ft	= 1,000 ft	2. Did pipe pass test?
Pipe Diameter, in	= 12 in	
Test Pressure, psi	= 150 psi	
Pipe Section, ft	= 13 ft	
Water Leaked, gal	= 20 gal	
Allowable Leakage, GPD/mi-in	= 30 GPD/mi-in	

1. Calculate the leakage rate in gallons per day.

$$\text{Leak Rate, GPD} = \frac{\text{Water Leaked, gal}}{\text{Test Duration, day}}$$

$$= \frac{\text{20 gallons}}{\text{1 day}}$$

$$= 20\text{ GPD}$$

2. Convert pipe length from feet to miles.

$$\text{Pipe Length, mi} = \frac{\text{Pipe Length, ft}}{\text{5280 ft/mi}}$$

$$= \frac{\text{1000 ft}}{\text{5,280 ft/mi}}$$

$$= 0.189\text{ mi}$$

3. Determine the actual leakage during the test in gallons per day per mile of pipe per inch of diameter.

$$\text{Actual Leakage, GPD/mi-in} = \frac{\text{Leak Rate, GPD}}{\text{(Length, mi)(Diameter, in)}}$$

$$= \frac{\text{20 GPD}}{\text{(0.189 mi)(12 in)}}$$

$$= 8.8\text{ GPD/mi-in}$$

4. Did the pipe pass the leak test?

Yes. Since the actual leakage rate was 8.8 GPD/mi-in which is less than the allowable leakage rate of 30 GPD/mi-in, the pipe passed the leak test.

EXAMPLE 7

A 6-hour leak test is performed on 500 feet of 6-inch plastic pipe with a test pressure of 150 psi. The pipes are 10 feet long. According to Table 6.1, the allowable leakage is 1.45 gallons per hour for each 100 joints of 6-inch pipe. During the 6-hour test period, 12 gallons of water were added to maintain the 150 psi pressure. Did the pipe pass the leak test?

Known		Unknown
Test Duration, hr	= 6 hr	1. Actual Leakage, gal per hr/100 joints
Pipe Length, ft	= 500 ft	
Pipe Diameter, in	= 6 in	
Test Pressure, psi	= 150 psi	2. Did pipe pass test?
Pipe Section, ft	= 10 ft	
Water Leaked, gal	= 12 gal	
Allowable Leakage, gal per hr/100 joints	= 1.45 gal per hr/100 joints	

1. Calculate the leakage rate in gallons per hour.

$$\text{Leak Rate, gal/hr} = \frac{\text{Water Leaked, gal}}{\text{Test Duration, hr}}$$

$$= \frac{12 \text{ gallons}}{6 \text{ hours}}$$

$$= 2 \text{ gallons per hour}$$

2. Determine the number of joints.

$$\text{Number of Joints} = \frac{\text{Pipe Length, ft}}{\text{Pipe Section, ft/joint}}$$

$$= \frac{500 \text{ ft}}{10 \text{ ft/joint}}$$

$$= 50 \text{ joints}$$

Since we have 50 joints, and not 100 joints, we have 0.5 — 100 joints.

3. Determine the actual leakage during the test in gallons per hour per 100 joints.

$$\text{Actual Leakage, gal per hr/100 joints} = \frac{\text{Leak Rate, gal/hr}}{\text{Number of 100 Joints}}$$

$$= \frac{2 \text{ gal/hr}}{0.5 \text{ — } 100 \text{ joints}}$$

$$= 4 \text{ gal per hr/100 joints}$$

4. Did the pipe pass the leak test?

No. Since the actual leakage was 4 gal per hr/100 joints which is greater than the allowable leakage rate of 1.45 gal per hr/100 joints for 6-inch pipe, the pipe did not pass the test.

3.658 Main Disinfection

During the construction of a new water line, there is a lot of opportunity for contamination of the line even if special precautions have been taken. Therefore, effective disinfection is necessary before the line is placed into service. The effectiveness of disinfection depends largely on maintaining clean pipes and avoiding major contamination during construction or repairs. Pipe crews must be trained to be aware of this need.

Precautions must be taken to protect the interiors of pipes, fittings and valves against contamination. When pipes are delivered to construction or repair sites they should be unloaded so as to minimize entrance of foreign material. Water-tight plugs must be used to close all pipeline openings when pipe laying is stopped for any reason. Joints of all pipe in the trench must be completed before work is stopped. If any water gets into the trench, the plugs must remain in place until the trench is dry. Packing and sealing materials must not contain any contaminated material or any material capable of supporting growth of microorganisms and should be handled so as to avoid contamination. If there is dirt in the pipe from wet-trench construction, flooding by a storm or an accident during construction which would probably not be removed by flushing, the pipes must be thoroughly cleaned. For more details on the disinfection of water mains, see Chapter 5, "Distribution System Operation and Maintenance," Chapter 6, "Disinfection."

3.659 Safety

The safety of the public and the operators must be protected at all times during the installation of pipe. Barricades should be put up on the curb side of the trench to limit accidental access by pedestrians. Whenever possible, the excavated material from the trench should be piled on the street side of the main to form a barricade to keep traffic away from the trench. If this is not possible, barricades should be put up and moved along as the work progresses. Easily visible construction signs, guards, torches and flagmen should be provided where needed for the protection of the public. In dense traffic, high signs are more visible. Children should be discouraged from playing near the job. At night, the excavated material, pipe and fittings, should be protected with flares and blinker lights.

Wherever the trenching destroys or interferes with the sidewalks used by pedestrians, wooden walkways at least 4-feet (1.2 m) wide should be provided. When open trenches interfere with traffic that must go through or driveways that must be used, steel plates over the trenches are required.

The need for shoring of the trenches will depend on the kind of soil, the depth of the trench, and the regulations of OSHA. Normally, unless the trench sides are sloped back at least 1 : 2, a trench 4-feet (1.2 m) deep or more requires shoring.

All operators must wear gloves and hard hats. They should always stand clear of obvious safety hazard situations such as pipe being lifted by mechanical equipment and the swinging buckets of backhoes. Steel-toe shoes should be worn to protect your feet. During pipe grinding and polishing, safety goggles must be worn.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 152.

3.65U What water pressure is used for a leakage test?

3.65V During grinding and polishing work on pipe, what safety precautions must be taken?

End of Lesson
3 of 5 on
DISTRIBUTION
SYSTEM
FACILITIES

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 3 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

10. Why should water and sewer lines be adequately separated?
11. How should pipe be stored on the job site before installation?
12. Where should the excavated soil from a trench be piled?
13. How can trenching accidents be prevented?
14. Why should other utility companies be notified before any excavation work?
15. How can operators in trenches be protected from cave-ins?
16. How can you determine the shoring requirements in your area?
17. How would you determine if there was leakage from a pipe during a leakage test?

CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 4 of 5 Lessons)

3.66 Pipe Extensions

Water systems must grow with the community they serve. New pipes may extend directly out from the end of an existing main or stub out from the side of the main. To simplify the extension, a line valve may already have been installed. If so, existing services need not be interrupted and the new connections can be quickly and easily made. To add a new main or lateral into an existing main where no line valve was installed, cut a hole in the main using a tapping saddle or sleeve. In a wet tap, you will bolt a valve to the tapping saddle; the actual drilling of the pipe through the valve can be done with the pipe under pressure. Tapping a drained line is referred to as a dry tap. Wet taps are preferred because water service is not interrupted. Also, if the pipe is drained, there is a possibility of contamination because any time the pressure in a pipeline is removed, contamination may more easily enter that line.

The tapping sleeve used for a wet tap is a split sleeve as shown in Figure 3.39. One half of the sleeve has an opening with a flange or some other means by which a valve can be attached. Fasten the sleeve around the pipe and make a tight joint at each end. Fasten a valve of a size suitable for the proposed pipe extension to the sleeve opening. Bolt a tapping machine on the other side of this valve. The tapping machine (Figure 3.40) carries a cylindrical cutter (the same size as the proposed branch) which is enclosed in a watertight case. Open the valve, move the cutter through the valve to the pipe, and cut a hole through the pipe. Withdraw the cutter into its case and close the valve. Remove the tapping machine. The valve remains permanently in place and the pipeline extension can be connected to it.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.66A How can a tap be installed in a water main under an operating water pressure?

3.66B How can new service connections be installed in existing plastic mains?

3.67 Appurtenances

3.670 Valves

3.6700 Types of Valves. Valves are used for many purposes in a distribution system. They can shut off, turn on and otherwise regulate the flow of water, reduce pressure, provide air and vacuum relief, blow off or drain water from parts of the system, and prevent backflow. Valves are one of the most important devices available in operating the water distribution system.

SHUTOFF AND FLOW REGULATION. The four most common types of valves encountered are the slide, rotary, globe, and diaphragm valves which can be used to provide starting and stopping functions and regulate flows. Not all slide valves, however, are used for flow regulation. These valves are shown in Figure 3.41.

Gate valves are the most common important type of slide valves used. Their main application in a distribution system is to isolate sections of mains to permit emergency repairs without interruption of service to large numbers of customers. A sliding flat metal disc (or discs) slightly larger than the flow opening is used. The disc is moved at right angles to the direction of flow by a screw-operated stem. Since the disc can be raised completely out of the water, little reduction in flow occurs when gate valves are installed in a pipeline. The surface of a disc may be made of bronze or other corrosion-resistant materials. In some cases, the entire disc is made of bronze. A cutaway view of one gate valve model is shown in Figures 3.42 and 3.43.

Various types of rotary valves are available including the ball, butterfly, and plug valves (Figure 3.41). Usually, a 90-degree rotation movement is used with a notch, arrow or other indicator to show valve positions. In the ball valve, the movable part is a ball with a cylindrical hole bored through it. When the ball is in one position there is a straight passage through the valve, but when it is rotated 90 degrees the flow is blocked. Ball valves should be operated either fully open or fully closed. If you attempt to control flow with a ball valve, the seal around the ball and the valve body could be destroyed and render the valve useless.

The butterfly valve has a movable disc as large as the full diameter of the pipe. The disc rotates on a spindle or shaft in only one direction to either block or allow the flow of water. Figures 3.44 and 3.45 show butterfly valves. Plug valves may have a tapered or cylindrical plug with an opening through the side which can be turned to open, restrict, or close the flow. The smaller plug valves are used extensively as corporation stops on service lines.

Globe valves are very efficient in either flow or pressure regulation. They are used almost exclusively on pipes four inches (100 mm) in diameter or smaller. A section through a globe valve is shown in Figure 3.46. A tapered or flat disc made of rubber or leather is used. The disc is raised or lowered onto a seat as in the common home faucet. Water flow is stopped when the disc contacts the seat. A needle design, which is used in some globe valves, provides precise adjustments of small flows. With this design, a protruding cone-shaped piece restricts or stops the flow.

In the diaphragm valve, a flexible piece inside the valve's body can be adjusted up or down using an attached stem. When the piece is depressed, the flow of water can be stopped or regulated. The piece is made of flexible material, such as rubber or leather, and is attached to the perimeter (outside edge) of the valve.

Summary information on the gate, butterfly, globe, ball and plug valves is given in Table 3.2. The common size range, use and main advantages and disadvantages are shown.

QUESTIONS

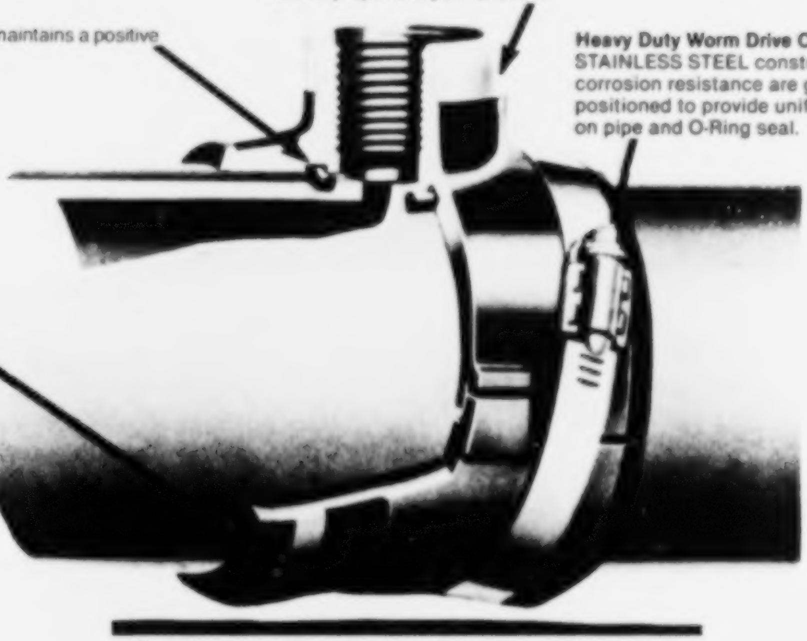
Write your answers in a notebook and then compare your answers with those on page 153.

3.67A List five types of valves.

3.67B What is the main application of gate valves in a water distribution system?

3.67C What are the two main uses of globe valves?

PRESSURE REGULATION. Valves which control water pressure operate by restricing flows (Figure 3.47). They are used to deliver water from a high pressure to a low pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening. An increase in the downstream pressure increases the pressure exerted against the diaphragm; as the spring is compressed it moves the valve element towards the seal, thereby decreasing the flow. When the downstream pressure decreases, the spring will open the valve element and permit more flow.



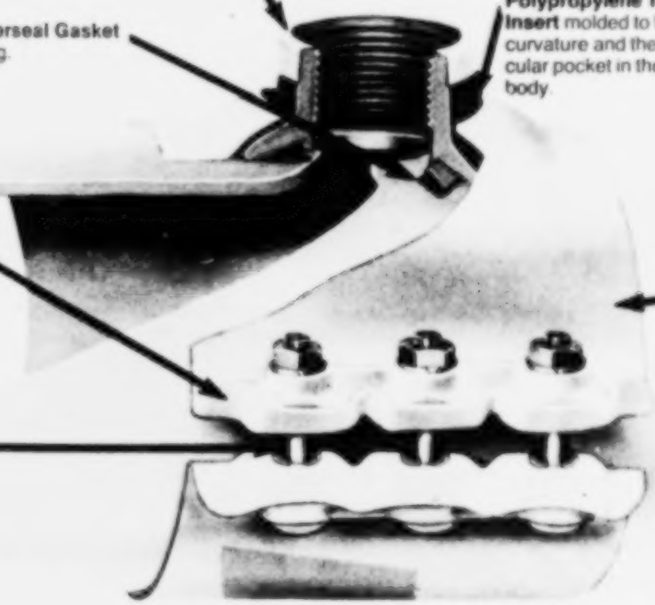
Stainless Steel Reinforcing Cap insures proper and permanent fit.

Grade 60 O-Ring maintains a positive hydraulic seal.

Heavy Duty Worm Drive Clamps of ALL STAINLESS STEEL construction for maximum corrosion resistance are geometrically positioned to provide uniform pressure balance on pipe and O-Ring seal.

Celcon M90 or Polypropylene Saddle Body is proportioned to fully encapsulate and protect pipe from undesirable stresses and deformation.

Saddles for plastic pipe sizes 1 inch through 4 inch



Stainless Steel Reinforcing Cap insures proper and permanent fit.

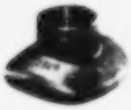
Grade 60 Taperseal Gasket self energizing.

Polypropylene Threaded Insert molded to fit the pipe curvature and the noncircular pocket in the saddle body.

Semi-Circular Rocker Bar of high impact plastic. Self aligning to prevent bolt distortion and eliminate areas of high stress concentration.

Saddle Body constructed of heavy sheet steel, epoxy coated to prevent corrosion. Formed to the contour of the tapped insert and rocker bar bolt supports.

Stainless Steel Bolts ⅜" × 2¾" with square neck and hex nuts. Saddles with tap sizes thru 1" have 4 bolts. Tap sizes larger than 1" have 6 bolts.



Optional Tapped Insert cast bronze.

Saddles for plastic pipe sizes 6 inch through 12 inch

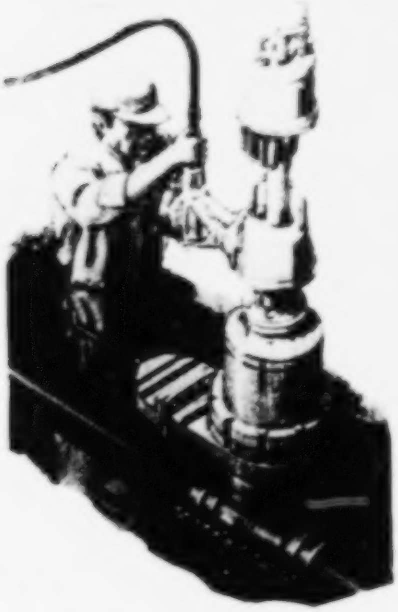
Fig. 3.39 Tapping saddles for plastic pipes

(Permission of Rockwell International)

Drilling machine makes service connections to plastic mains by drilling the mains through a combined clamp and corporation stop.

Service connections can be made on any type of main under pressure by drilling through a corporation stop and service clamp.

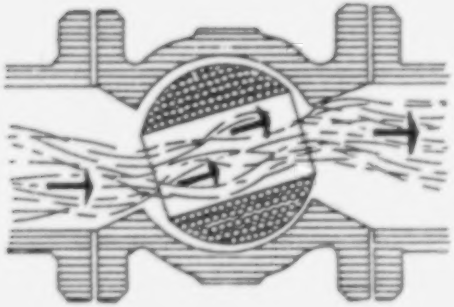
Lateral branch main connections can be made by drilling through a tapping sleeve and valve with a drilling machine.



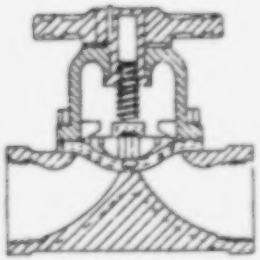
New gate valves can be added to existing systems by drilling the main through an inserting valve assembly and inserting the gate valve, all under pressure and without loss of water.

Fig. 3.40 Drilling and tapping machines

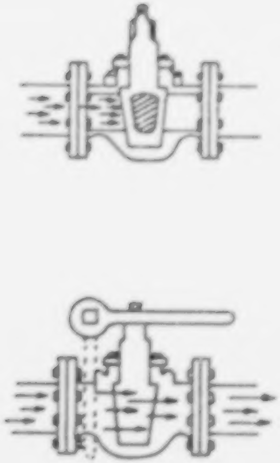
(Permission of Mueller Co. Copyright February 1971, Mueller Co.)



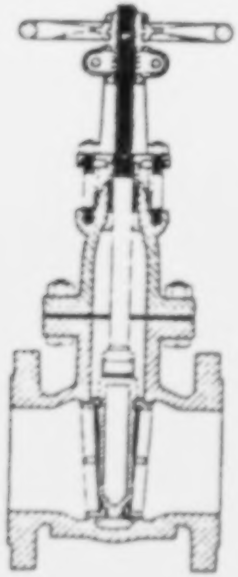
BALL VALVE



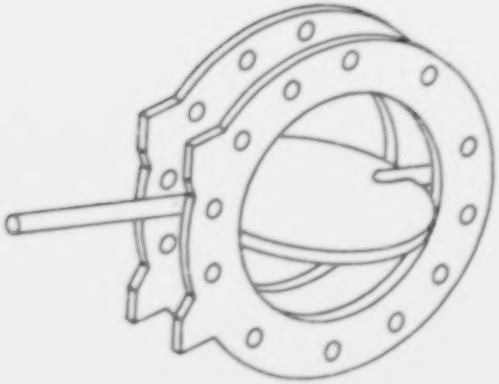
DIAPHRAGM VALVE



PLUG VALVE



GATE VALVE



BUTTERFLY VALVE

Fig. 3.41 Valve types

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

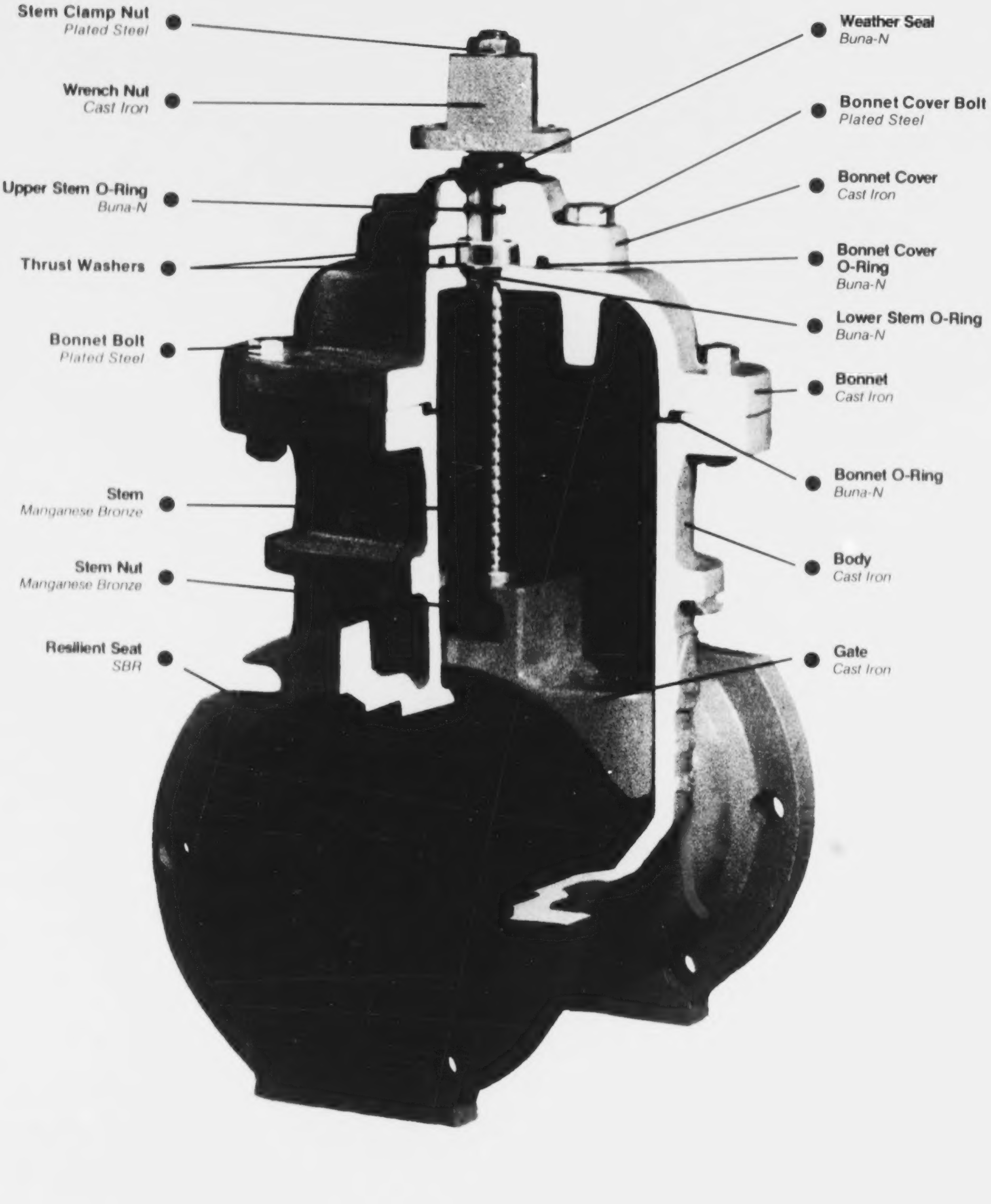
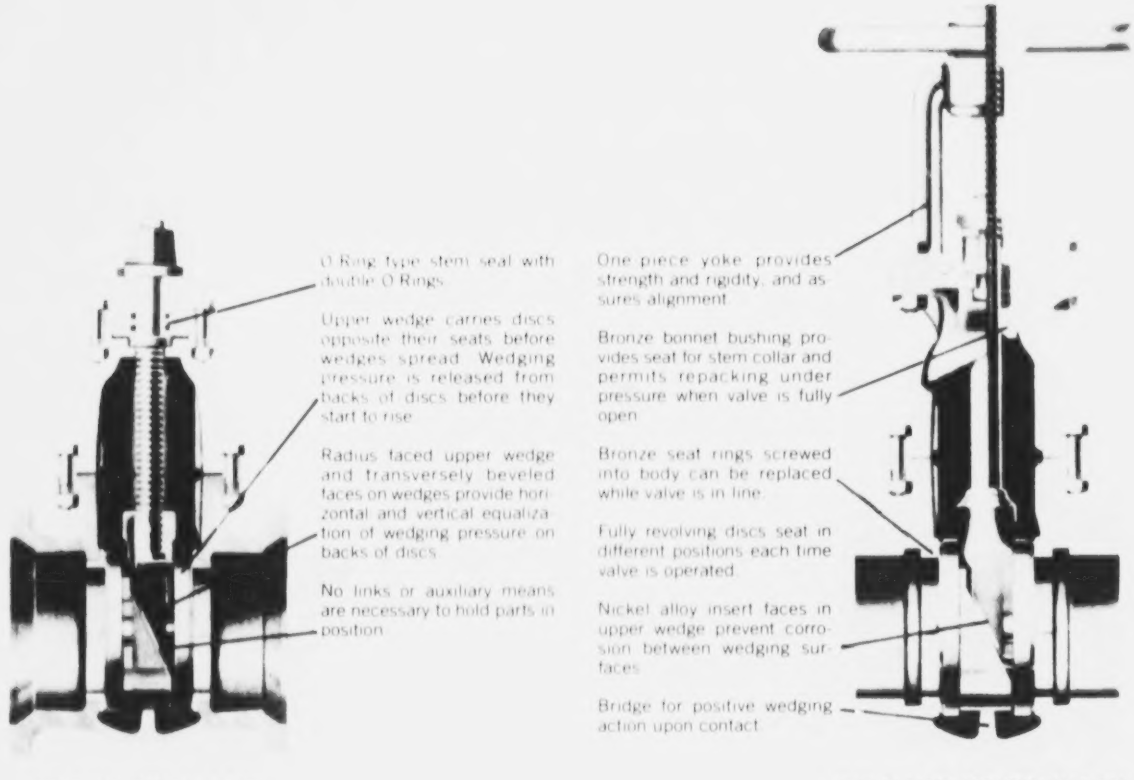

Stem Clamp Nut
Plated Steel
Wrench Nut
Cast Iron
Upper Stem O-Ring
Buna-N
Thrust Washers
Bonnet Bolt
Plated Steel
Stem
Manganese Bronze
Stem Nut
Manganese Bronze
Resilient Seat
SBR
Weather Seal
Buna-N
Bonnet Cover Bolt
Plated Steel
Bonnet Cover
Cast Iron
Bonnet Cover
O-Ring
Buna-N
Lower Stem O-Ring
Buna-N
Bonnet
Cast Iron
Bonnet O-Ring
Buna-N
Body
Cast Iron
Gate
Cast Iron

Fig. 3.42 Gate valve parts

(Permission of American Valve and Hydrant,
A Division of American Cast Iron Pipe Company)



O Ring type stem seal with double O Rings.

Upper wedge carries discs opposite their seats before wedges spread. Wedging pressure is released from backs of discs before they start to rise.

Radius faced upper wedge and transversely beveled faces on wedges provide horizontal and vertical equalization of wedging pressure on backs of discs.

No links or auxiliary means are necessary to hold parts in position.

One piece yoke provides strength and rigidity, and assures alignment.

Bronze bonnet bushing provides seat for stem collar and permits repacking under pressure when valve is fully open.

Bronze seat rings screwed into body can be replaced while valve is in line.

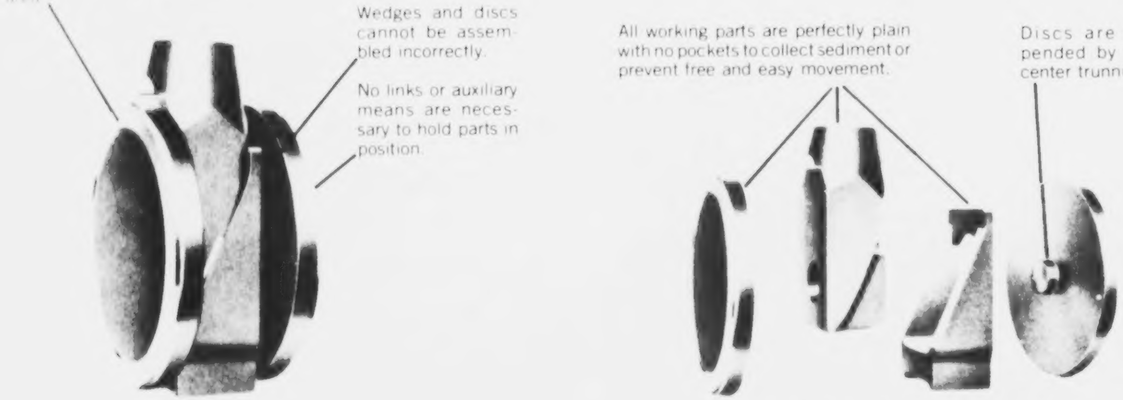
Fully revolving discs seat in different positions each time valve is operated.

Nickel alloy insert faces in upper wedge prevent corrosion between wedging surfaces.

Bridge for positive wedging action upon contact.

NON-RISING STEM VALVE (NRS)

OUTSIDE SCREW AND YOKE VALVE (OSY)



Extra wide disc and seat ring faces provide large seating area.

Wedges and discs cannot be assembled incorrectly.

No links or auxiliary means are necessary to hold parts in position.

All working parts are perfectly plain with no pockets to collect sediment or prevent free and easy movement.

Discs are suspended by their center trunnions.

DISCS AND WEDGES—(Shown Assembled)

DISCS AND WEDGES—(Shown Separated)

SIMPLICITY AND RUGGEDNESS OF DESIGN ASSURES TIGHT CLOSING, LONG LIFE, AND EASY OPERATION

Fig. 3.43 Gate valve sectional views

(Permission of American Valve and Hydrant, A Division of American Cast Iron Pipe Company)

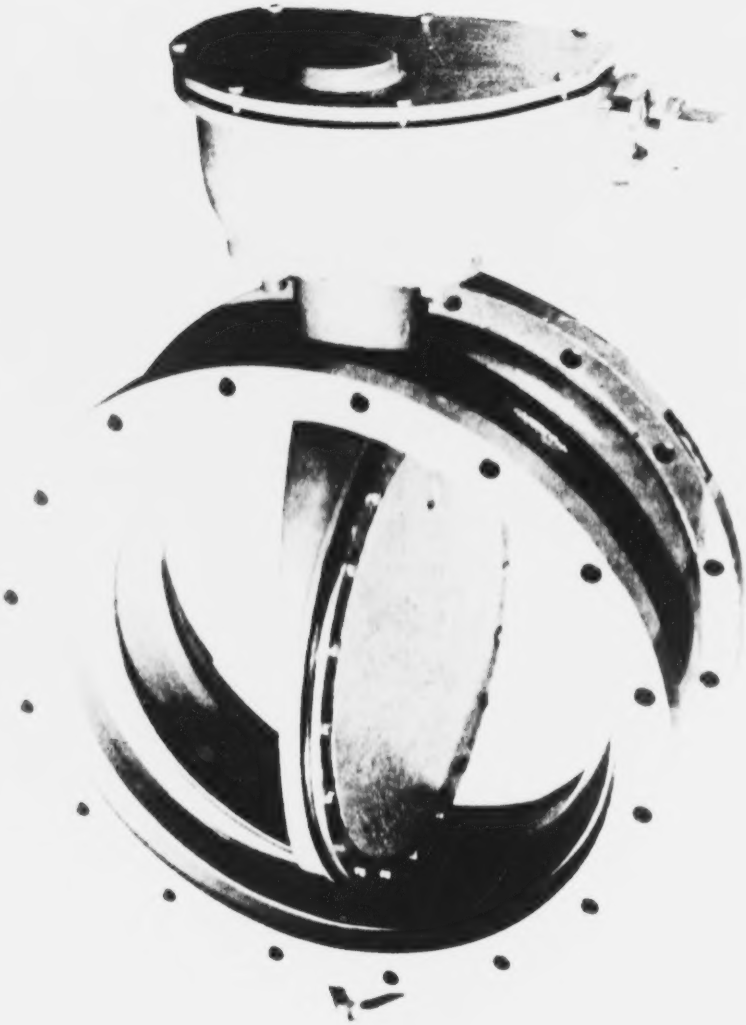
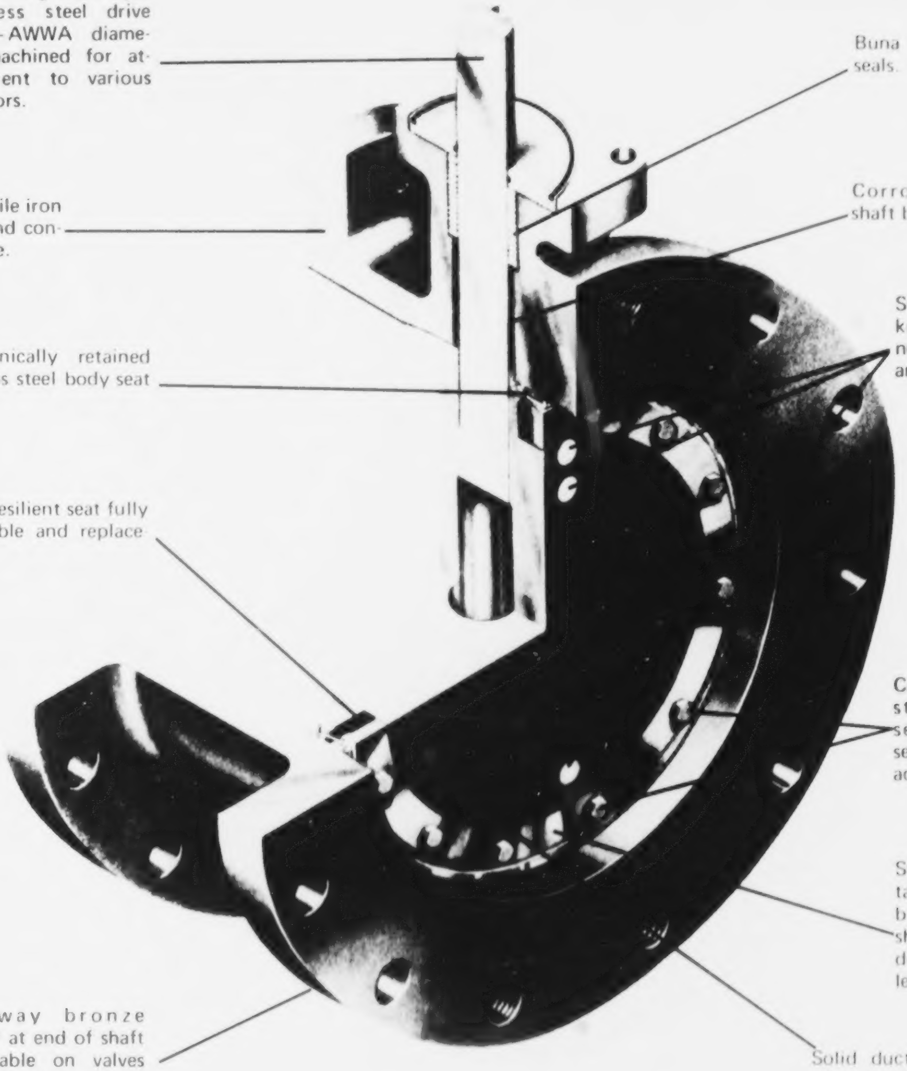


Fig. 3.44 Butterfly valve

(Permission of American Valve and Hydrant,
A Division of American Cast Iron Pipe Company)



Special high strength stainless steel drive shaft—AWWA diameters—machined for attachment to various operators.

Buna N vee ring stem seals.

Corrosion resistant shaft bearings.

High tensile ductile iron body. Various end connections available.

Stainless steel wedge keys assure rigid connection between shaft and disc.

Mechanically retained stainless steel body seat ring.

360° Resilient seat fully adjustable and replaceable.

Cap screws of stainless steel through rubber seat provide positive seat retention and seat adjustment.

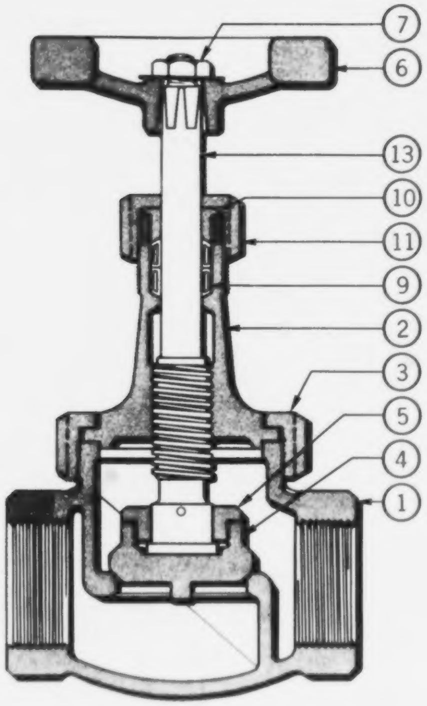
Stainless steel ring retains rubber seat to disc by means of offset shoulders in seat and disc, fastened by stainless steel cap screws.

Two-way bronze thruster at end of shaft—adjustable on valves 30" and larger (not shown in this view).

Solid ductile iron disc of streamlined design.

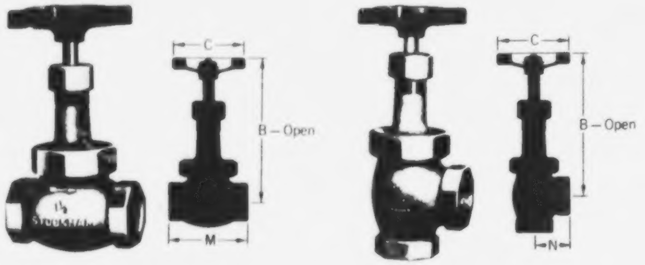
Fig. 3.45 Butterfly valve sectional view

(Permission of American Valve and Hydrant, A Division of American Cast Iron Pipe Company)



NO.	DESCRIPTION	MATERIAL	ASTM SPEC.
1	BODY	BRONZE	B-61
2	BONNET	BRONZE	B-61
3	BONNET RING	BRONZE	B-61
* 4	DISC	COPPER-NICKEL ALLOY (¾-3)	B-584 Alloy 976
5	DISC NUT	BRASS (¾-1)	B-16
		BRONZE (1¼-3)	B-62
6	HANDWHEEL	MALL. IRON	A-197
7	HANDWHEEL NUT	STEEL-ZINC PLATED	
9	PACKING	TEFLON® IMPREGNATED ASBESTOS	
10	PKG. GLAND	BRASS	
11	PKG. NUT	BRONZE	B-62
13	STEM	COPPER-SILICON ALLOY	B-371 Alloy 694

*Sizes 1/4-1/2 Integral with Stem



Globe Valve

Angle Valve

Fig. 3.46 Globe and angle valves
(Permission of Stockham Valves and Fittings)

TABLE 3.2 VALVE SUMMARY[a]

Valve Type	Common Size Range, in.	Particularly Adapted to	Main Advantages	Main Limitations
Gate valve	½-24	isolation service in pipe grids	low cost in small sizes; low friction loss; fairly good service life; ease of installation	high cost in large sizes; large valves are quite heavy; poor for throttling; should not be used where frequent operation is necessary
Butterfly valve	12-60	isolation and automatic control	low cost in larger sizes for normal service pressures; some types have very short lengths; ease of operation	higher friction loss than gate valve; must use care in selecting valve, particularly for line-break flow conditions; may cause problems when relining pipe; often leaks because of seat damage
Globe valve	½-24	isolation in small sizes, flow control in large sizes, pressure control	simple construction; dependable; can be used for throttling; good for pressure control; sediment or material unlikely to prevent complete closing	high friction loss; very heavy and expensive in large sizes
Ball and plug valves	¾-2	isolation and throttling	dependable; very low friction loss; slow shutoff characteristic minimizes closing surges; ease of operation	expensive; very heavy

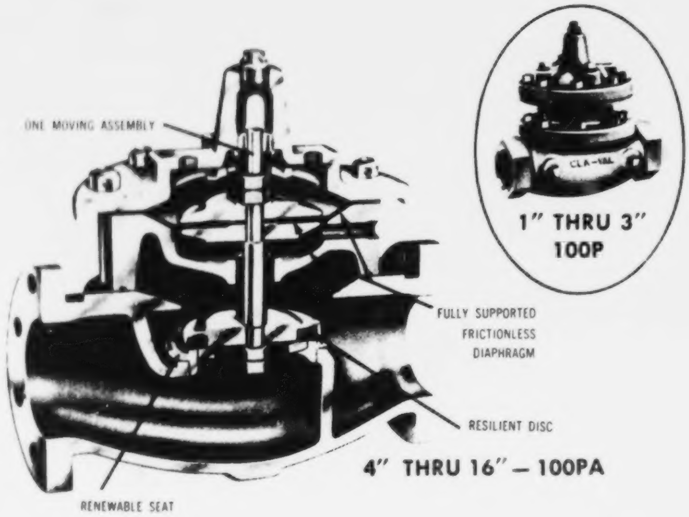
[a] *WATER DISTRIBUTION OPERATOR HANDBOOK*, available from Computer Services, AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235. Order No. 20103. Price to members $13.00, nonmembers $16.50.

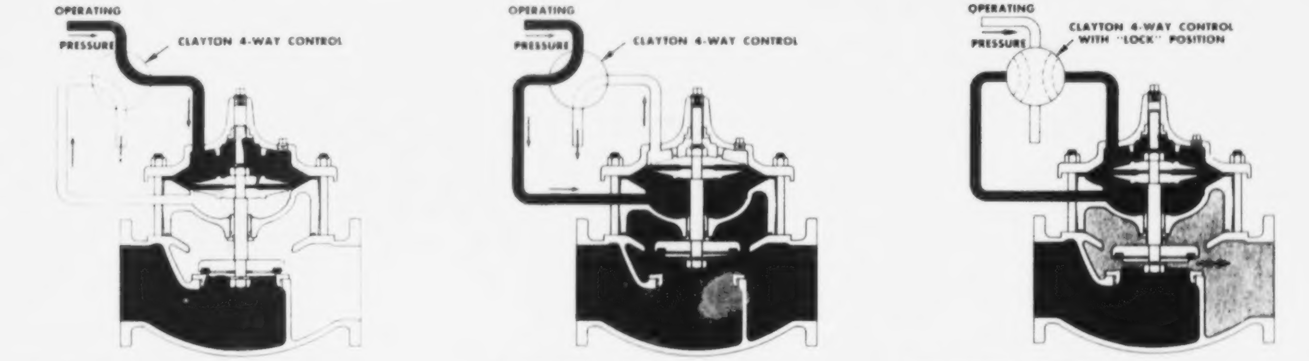
DESCRIPTION

The Clayton Powertrol is a globe type valve, containing two operating chambers sealed from each other by a flexible, reinforced diaphragm. The lower chamber, or power chamber is also sealed from line pressure. Standard operation arrangement requires a four-way pilot control.

OPERATION

When operating pressure is applied above the diaphragm and removed from below, the valve closes tight. When these conditions are reversed, the valve opens wide. Rate of opening or closing is controlled by throttling the exhaust pressure. A locked position for any desired degree of opening can be accomplished.





TIGHT CLOSING OPERATION

Valve closes drip-tight when operating pressure is applied above diaphragm and removed from below.

FULL OPEN OPERATION

Valve opens wide when operating pressure is removed from chamber above diaphragm and applied to chamber below diaphragm. Flow in either direction is permitted through valve.

THROTTLING ACTION

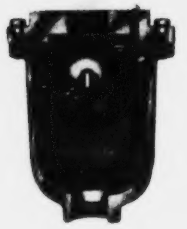
Valve holds any intermediate position when operating pressure is trapped above and below the diaphragm. Any controlling pilot valve can be used which provides four way action with a "lock" position in which no flow through pilot occurs.

Fig. 3.47 Pressure regulation valve

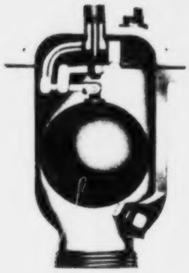
(Permission of CLA-VAL Company)

PRESSURE REDUCING AND PRESSURE SUSTAINING. For these functions, valves can be used separately or in combination. One valve can maintain a constant downstream pressure regardless of fluctuating demand while the other valve will hold the pressure at a pre-determined minimum pressure. These valves are usually of a globe design controlled by a diaphragm with the diaphragm assembly being the only moving part. A resilient (material that springs back into shape) disc is held by a disc retainer and forms a tight seal with the valve seat when pressure is applied above the diaphragm flow. The open, closed, and in-between positions are controlled by small pilot valves and pressures sensed upstream and downstream of the valve. By sensing differential pressures across an orifice plate, the hydraulically operated disc globe valve can become an automatic, flow-control valve.

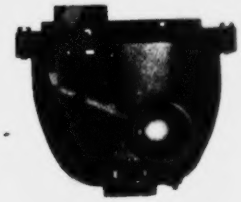
AIR AND VACUUM RELIEF. Both of these functions are usually combined in one valve unit. Air can cause serious pipeline problems. Air may get into the water through pumps, packing glands, leaky joints, or it may already be in the water as it enters the system. Once in the system air tends to collect at high points in the lines. These air pockets can increase the resistance to flow by 10 to 15 percent, and it is even possible for an air-lock condition to occur and stop the flow of water completely. Vacuum conditions sometimes develop when mains are being drained and can cause the collapse of pipelines, even of large steel pipes. Air relief valves are most effective when installed at high points in the line. A very simple type of air valve has no moving parts except a float, or the float may be connected to a hinged rubber stopper that seals the outlet (Figure 3.48). Normally, the outlet is sealed by either the float itself or the stopper. If air accumulates, the water level goes down and the float or stopper drops away from the outlet opening allowing the air to escape. After the air is released, the water level rises and the float or stopper reseals the outlet. These valves can combine three functions. They can allow large quantities of air to escape during the filling of a pipeline, permit air to enter a pipeline that is being drained, and allow entrained air to escape while a line is operating under pressure.



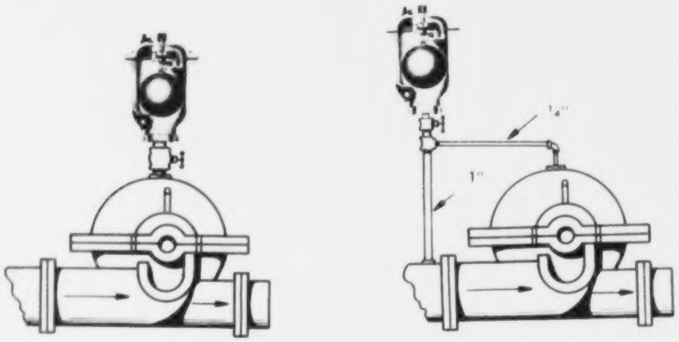
1. Air and Vacuum Valve



2. Air Release Valve



3. Combination Air Valves



4. Air Release Valves for Centrifugal Pumps

5. Air Valve for Vertical Turbine Pumps

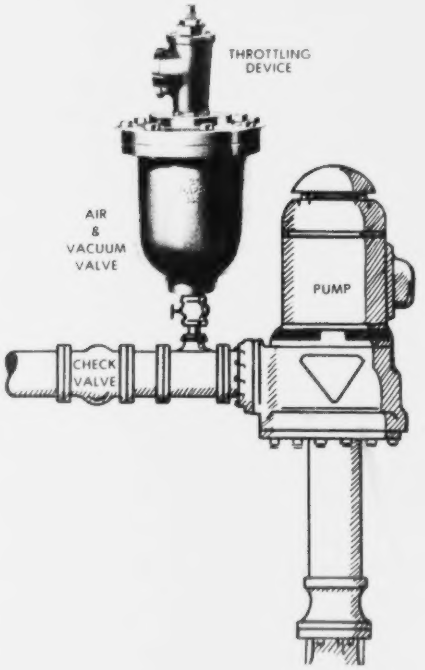

THROTTLING DEVICE
AIR & VACUUM VALVE
PUMP
CHECK VALVE

Fig. 3.48 Air valves

(Permission of APCO Valve and Primer Corporation)

Figure 3.48 shows various types of air valves and typical installations. Air and vacuum valves (Drawing 1) have a large orifice which permits great amounts of air to escape from a system while it is being filled. Air release valves (Drawing 2) have much smaller orifices than the air and vacuum valves. Air release valves release the small pockets of air which gather at the high points of a system after it is filled and under pressure. Combination air valves (Drawing 3) combine the features of both the air and vacuum valve and the air release valve. Drawing 4 shows air release valves installed on centrifugal pumps while Drawing 5 shows an air and vacuum valve on a vertical turbine pump.

Slow closing air valves (Figure 3.49) are designed to eliminate critical shock conditions in those installations where operating conditions cause a regular air valve to slam shut. When pump discharge velocities exceed 10 feet per second (3 m/s), a slow closing air valve will prevent water hammer, muffle noise, and contain spillage. These valves consist of an air and vacuum valve mounted on top of a surge check unit. The air valve operates in the normal fashion allowing air to escape freely at any velocity (Figure A). The surge check unit operates on the interphase between the kinetic energy in the relative velocity flows of air and water, so that air passes through unrestricted, but when water rushes into the surge check unit, a disc commences to close and reduces the rate of flow of water into the air valve by means of throttling holes in the disc (Figure B).

PRESSURE RELIEF. Surge pressures occur in systems whenever the water velocity is suddenly changed, either decreased or increased. Typical causes of sudden changes of velocity are quick opening or quick closing of a line valve or sudden starting or stopping of a pump. If this occurs, the built-up energy of the flowing water produces a high pressure that may result in damage. Some type of surge control is needed and although surge tanks are sometimes used, the simplest type of control is the use of pressure relief valves. These valves respond to pressure variations at their inlets. They open very rapidly at an increase in pressure above the set point of the control and discharge the air to the atmosphere. They are most commonly installed on the side outlet of a tee at a specific point in a system.

VALVE PROTECTION. Air, vacuum and pressure relief valves must be protected against possible contamination. Do not install air and vacuum relief valves in pits unless you are able to protect them against flooding. Screen air inlets and outlets to prevent insects and rodents from entering the valve. Pressure relief valves must never be directly connected to sewer or storm drains.

OTHER VALVE APPLICATIONS. Valves are also available for the uses described below.

Altitude valves are used mainly on supply lines to elevated tanks or stand pipes. They close automatically when the tank is full and open when the pressure on the inlet side is less than that on the tank side of the valve. They control the high water level and prevent overflow.

Blow-off and drain valves are used primarily for blowing off accumulated sediment from low spots in the line and for dewatering lines or reservoirs for repairs or inspections.

Float-controlled valves control the level of water in storage tanks and may activate remote control equipment.

Backflow-prevention valves will stop the flow of an unapproved and possibly contaminated supply into the domestic water system. These valves are discussed further in Section 3.8, "Customer Service."

Check valves are used in the discharge side of pumps to prevent backflow. For additional information on check valves, see Chapter 3, Wells, Section 3.210, "Check Valves," in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE* and Chapter 18, Maintenance, in *WATER TREATMENT PLANT OPERATION*, Volume II, in this series of manuals.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.67D What type of valve design is used in pressure regulating valves?

3.67E What problems can be created when air gets into water?

3.67F Air relief valves can serve what three functions?

3.67G What is the purpose of blow-off valves?

3.6701 Valves Boxes and Vaults (Figure 3.50). Valve boxes provide access to buried valves. Their construction is similar to that of residential curb boxes. A valve key turns the valve stem from the top of the structure. Valve boxes are often made in two or more sections which telescope to give an adjustable length allowing the top of the box to be set at ground level.

Vaults are normally used for larger valves where access is needed for maintenance operations. Space is usually provided so that at least one person will be able to work on the valve or equipment. Valve vaults should be properly vented and drained. Inadequate draining may result in a flooded vault and a backsiphonage hazard. Special safety considerations must be taken into account with the deep vaults. You will need to pump air continuously into the vault and should use an atmospheric test meter to check for sufficient oxygen and harmful gases (explosive and toxic).

3.6702 Distribution System Valve Layout. Any water piping system should have valves in enough locations that relatively small parts of the system can be shut off for repairs or replacement without putting large areas out of service. Gate valves are normally used for this purpose. In general, provide enough valves so that repair work will not shut down a feeder main or a length of pipe greater than 1000 feet (300 m). Some utilities use a maximum separation distance of 500 feet (150 m). A typical valving arrangement is shown in Figure 6.50. In general, valves should be located on all branches from feeder mains and between mains and fire hydrants. Three valves should be used at crosses and two at tees.

Valves should be located uniformly throughout the system in relation to street intersections (see Figure 3.51). Some utilities standardize the valve locations by putting them at the same corners of each intersection. This procedure makes it easier to find the valves in an emergency.

3.6703 Valve Operation. Valves may be operated manually, by water pressures (hydraulic or pneumatic), or electrically. To operate a valve manually, use a wrench or turn a hand wheel on the valve. In valves controlled by water pressures, the valve stem passes through a packing ring and is joined to a piston in a closed chamber. Water under pressure enters the chamber below the piston and any water in the chamber above the piston is permitted to escape. This lifts the piston and opens the valve. To close the valve, the pressure and release procedures are reversed. Solenoids and electric motors geared to the valve mechanism are also used to open and close valves.

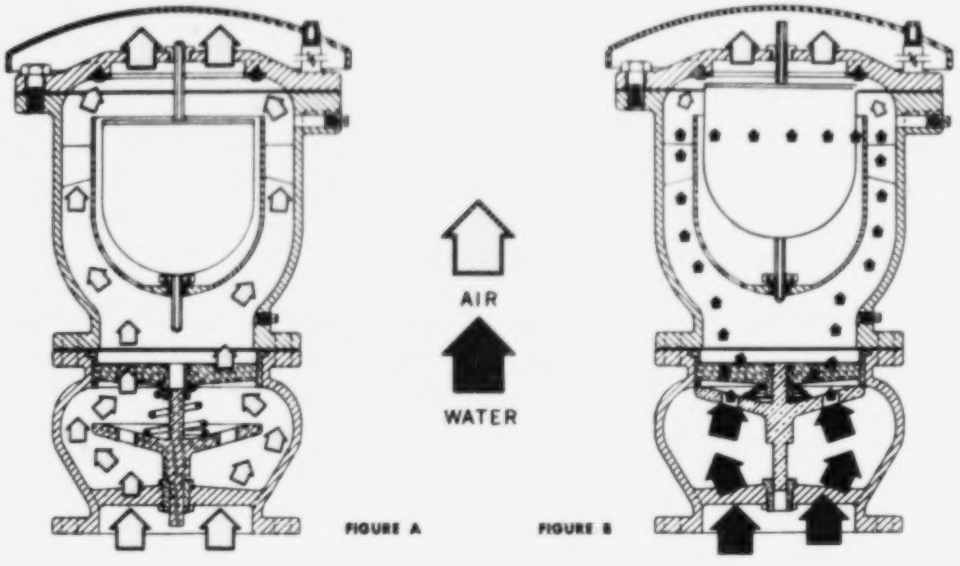


Fig. 3.49 Slow closing air valve
(Permission of APCO Valve and Primer Corporation)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.67H Why are valve boxes installed?

3.67I What problems could develop if a deep valve vault becomes flooded?

3.67J How many valves should be located at pipe crosses?

3.67K How are valves opened or closed?

3.671 Fittings

Pipe fittings are used for a number of different purposes in a water system. They connect pipes of the same size or different sizes, change the direction of flow, or stop the flow. Fittings can be obtained in most materials and sizes. Some can connect pipes made of dissimilar materials and others can connect pipes with different types of ends. Table 6.3 summarizes the various types of pipe fittings available.

TABLE 3.3 VARIOUS TYPES OF PIPE FITTINGS

CONNECTORS
Clamps
Sleeves
Couplings
Adapters
Expansion Joints

REDUCERS
Reducing Flanges
Tees
Crosses
Y-Laterals

CHANGE FLOW DIRECTION
Elbows
Tees
Bends

STOP FLOW
Caps
Plugs
Blind Flanges

TAPPING
Tapping Sleeves
Tapping Crosses
Tapping Clamps

Figure 3.52 shows some standard cast iron pipe bell-and-spigot fittings, while Figure 3.53 shows standard steel pipe fittings.

Valves used in pipe systems are inserted into couplings, some of which are shown in combination with various valve designs in Figure 3.54.

3.672 Hydrants (Figure 3.55)

Hydrants are used to fight fires, flush pipelines, and to provide water to water trucks or other construction equipment. They are generally made up of four parts: (1) the inlet pipe connection from the water supply main, (2) the main valve, (3) the barrel and (4) the head.

The two different types of fire hydrants commonly used are the dry-barrel and wet-barrel hydrants (Figure 3.56). The compression, gate and Corey hydrants shown in this figure are the dry-barrel type. The operating valve on dry-barrel hydrants is located at the bottom which makes it possible to empty all the water in the hydrant and to prevent any damage that might be caused by freezing. Wet-barrel hydrants have their operating valve at the outlet and can only be used in areas where winters are mild and freezing is not likely. They are sometimes called the California hydrant.

Post hydrants extend above ground and are the most commonly used type. However, the flush-type hydrant, with its operating nut and hose nozzles located in a cast iron box below ground level, has been installed in some locations. These are not recommended in areas of heavy snowfall.

There are a number of other fire hydrant design features that are of interest. Two-, three- and four-nozzle arrangements are used, with the two-nozzle, one-pumper connection arrangement being the most common. Nozzles are usually 2½ inches (63 mm) in diameter with pumper connections having a diameter of 4½ inches (11.3 mm). Protective caps over the nozzle ends are needed to safeguard the nozzle threads. Hydrant designs generally permit lifting the

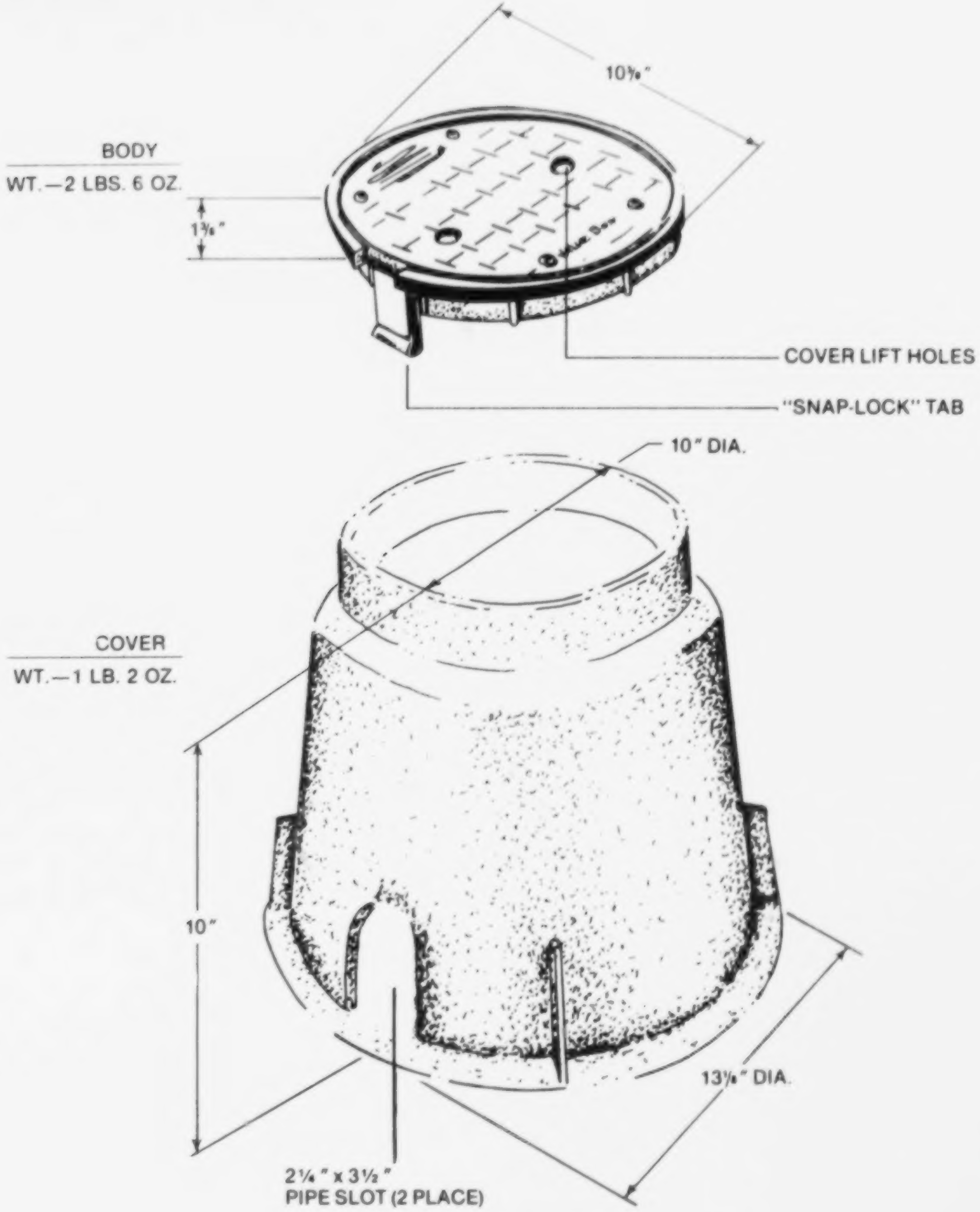

10⅞"
BODY
WT.—2 LBS. 6 OZ.
1⅜"
COVER LIFT HOLES
"SNAP-LOCK" TAB
10" DIA.
COVER
WT.—1 LB. 2 OZ.
10"
13⅛" DIA.
2¼" x 3½"
PIPE SLOT (2 PLACE)

Fig. 3.50 Valve box

(Permission of Hefner Plastics, Inc.)

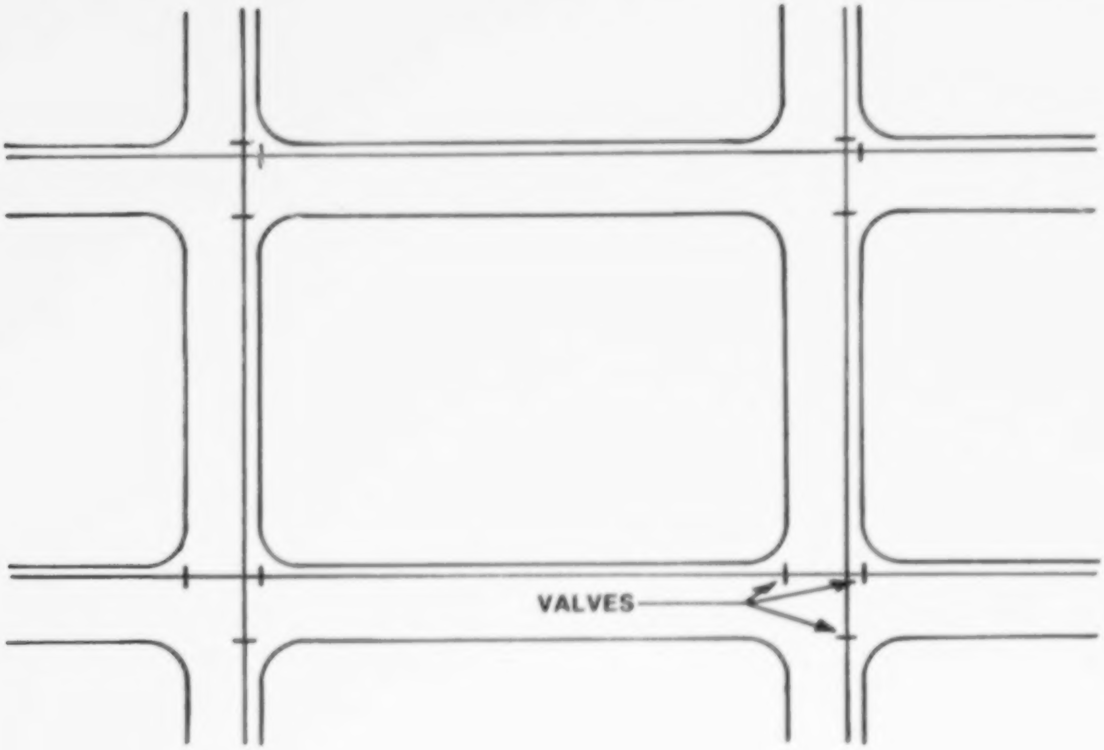


Fig. 3.51 Typical valve locations in streets

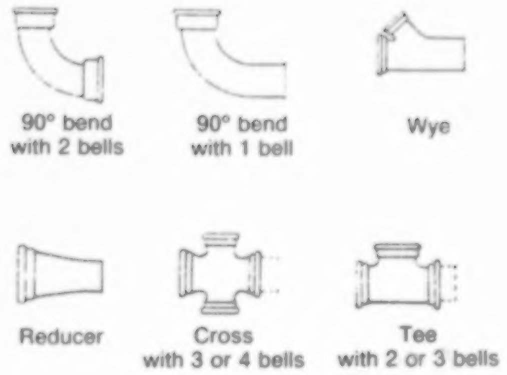
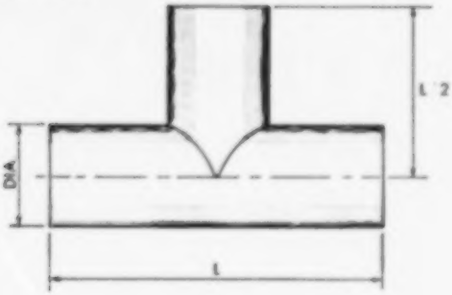

90° bend
with 2 bells
90° bend
with 1 bell
Wye
Reducer
Cross
with 3 or 4 bells
Tee
with 2 or 3 bells

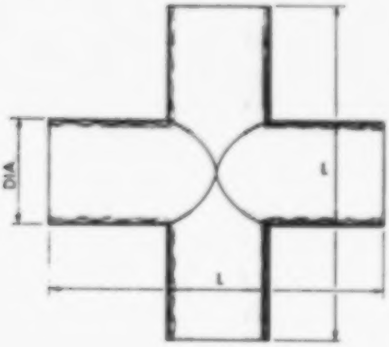
Fig. 3.52 Standard bell-and-spigot fittings

(Reprinted from *WATER-RESOURCES ENGINEERING*, Second Edition, by Linsley and Franzini, by permission. Copyright 1972, McGraw-Hill Book Company.)

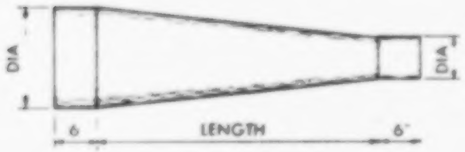
FITTINGS



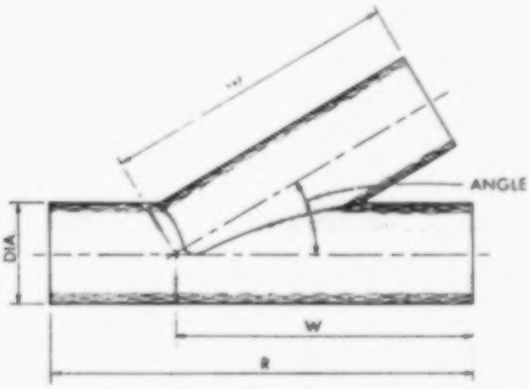
Tee



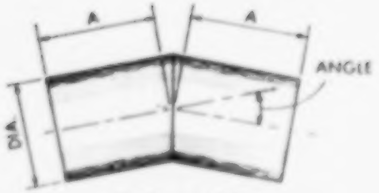
Cross


DIA.
DIA.
6"
LENGTH
6"

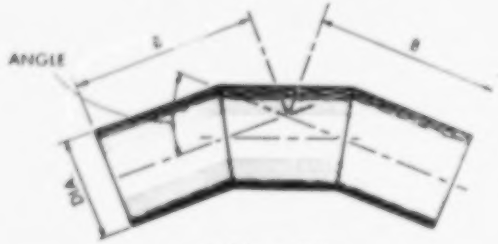
Reducer


W
ANGLE
DIA.
W
R

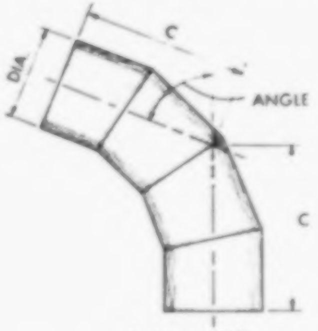
Wye


A
A
ANGLE
DIA.

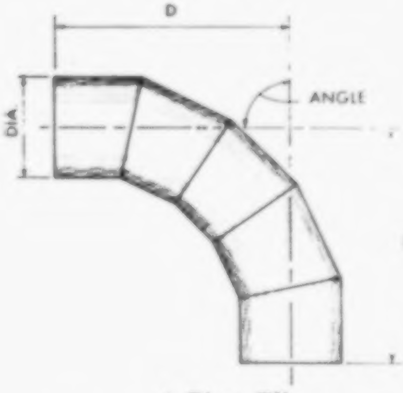
2 Piece Ell
0° to 22½° inclusive


ANGLE
B
B
DIA.

3 Piece Ell
Over 22½° to 45° inclusive


C
DIA.
ANGLE
C

4 Piece Ell
Over 45° to 67½° inclusive


D
DIA.
ANGLE
D

5 Piece Ell
Over 67½° to 90° inclusive

Fig. 3.53 Standard steel pipe fittings

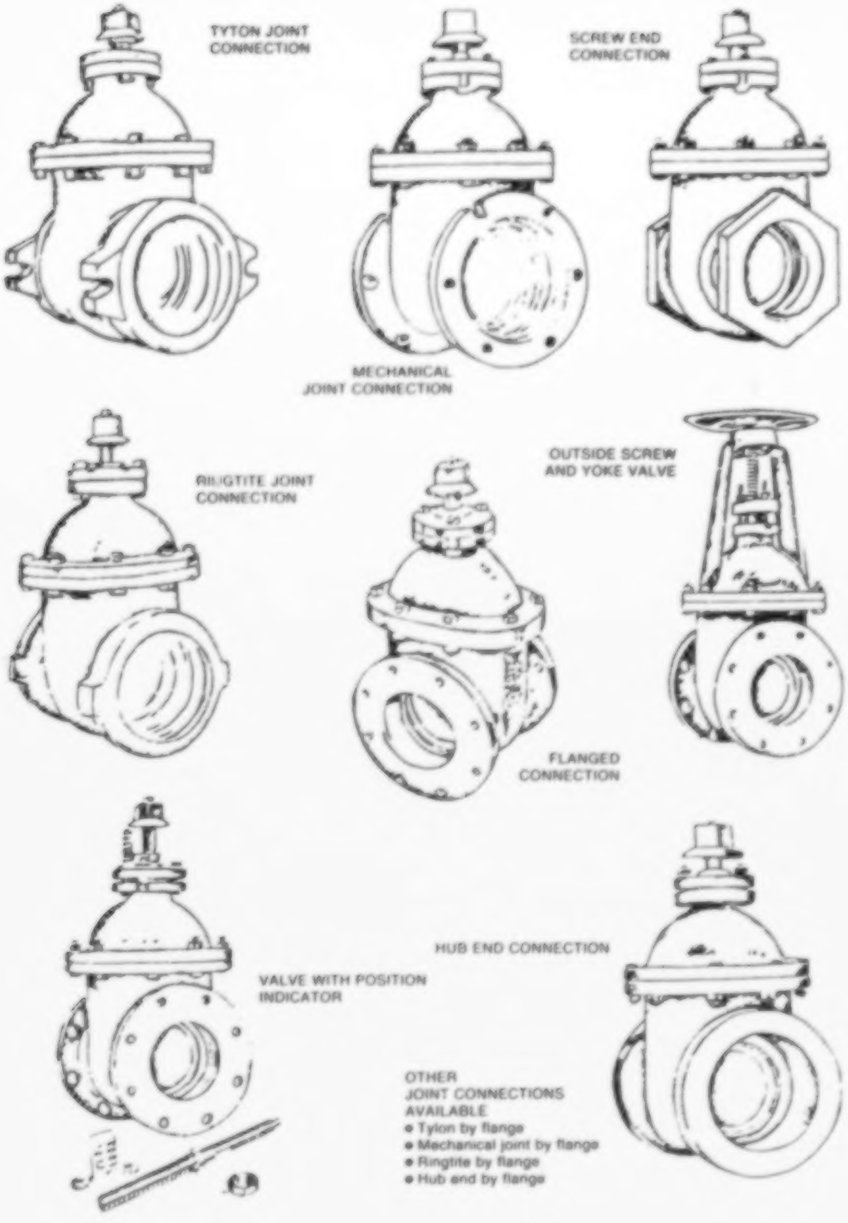

TYTON JOINT CONNECTION
SCREW END CONNECTION
MECHANICAL JOINT CONNECTION
RINGTITE JOINT CONNECTION
OUTSIDE SCREW AND YOKE VALVE
FLANGED CONNECTION
HUB END CONNECTION
VALVE WITH POSITION INDICATOR
OTHER JOINT CONNECTIONS AVAILABLE
• Tyton by flange
• Mechanical joint by flange
• Ringtite by flange
• Hub end by flange

Fig. 3.54 Valve Couplings

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

❶ **OPERATING NUT**—cast one-piece bronze operating nut directly actuates hydrant rod. Extra-long, close tolerance threads assure long life and easy operation. Grease groove insures complete lubrication of threads and thrust bearing. Lead of the operating thread permits slow closing of the hydrant valve, eliminating water hammer.

❷ **O-RINGS**—seal lubrication chamber, eliminate stuffing box, assure dry top hydrant, reduce friction, prevent water from reaching the operating mechanism.

❸ **HYDRANT ROD**—furnished in two sections of high tensile steel. Upper section has bronze sleeve where it passes through O-ring and has bronze stop nut to limit travel of rod. Lower section has a cadmium-plated spring with heavy bituminous coating to insure positive drain closure. Both sections are connected by cast iron coupling and pins. Rod directly operates hydrant valve and drains without need for auxiliary connections.

❹ **HYDRANT VALVE**—consists of a hydrant valve top, hydrant valve bottom and special hydrant valve rubber of concical shape. Hydrant valve bottom is threaded and screwed to valve rod, protecting rod threads from corrosion. Thread locking compound prevents loosening in service. Hydrant valve seats against the bronze hydrant seat.

❺ **HYDRANT SEAT**—made of special bronze, with accurately machined seat for hydrant valve and tapered drain ports.

❻ **HYDRANT SEAT DRAIN RING**—securely held between barrel and base flanges, provides bronze-to-bronze threaded connection for hydrant seat. Serves as non-corrosive multiport drain channel.

❼ **DRAIN LEVER**—rugged special bronze three-port drain performs dual function as carrier for drain lever washers and as wrench to remove working parts.

❽ **SOCKET HEAD PIPE PLUG**—sealed grease chamber. No greasing required as long as rod is intact. Grease fitting can replace plug for greasing.

❾ **COVER**—cast iron cover is quickly removed by unbolting two bolts. The word "open" and an arrow show direction to turn the operating nut.

❿ **HOUSING AND HOUSING COVER**—retains operating nut and thrust bearing. Rugged construction supports pressure and operating forces.

⓫ **THRUST BEARING**—takes upward thrust when opening and closing hydrant valve and reduces operating torque. Bearing is lubricated through top of operating nut.

⓬ **BARREL**—large high-strength cast iron barrel is flanged at ground line with 8 bolts, permitting installation in eight different positions. Large barrel delivers water to nozzles with no perceptible pressure loss. A ductile iron lower barrel and flanges provide extra ruggedness.

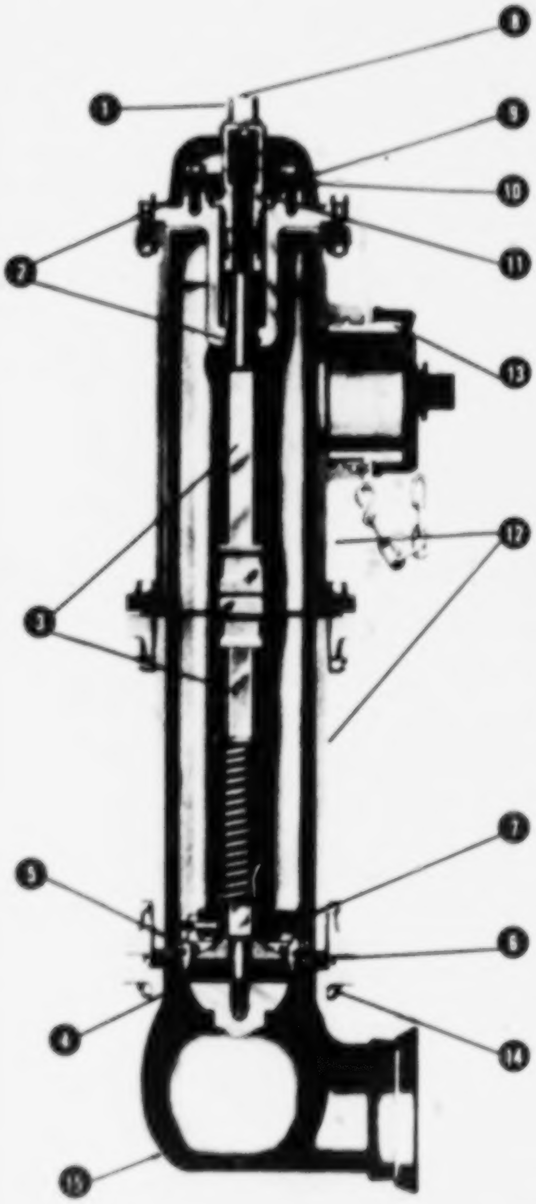
⓭ **NOZZLES**—Bronze nozzles are streamlined and have micrometer checked threads.

⓮ **BOLTS AND NUTS**—all bolts and nuts are cadmium plated.

⓯ **BASE**—large, spherical-shaped base has no projections or cavities to obstruct flow or collect sediment.

All American B-62-B barrel castings are painted inside and outside with a special primer. Section below ground level is given two coats of special black asphaltum paint which resists corrosion from moisture and soil. Exterior surface above ground is painted with special primer and high-grade enamel to customer's color requirement.

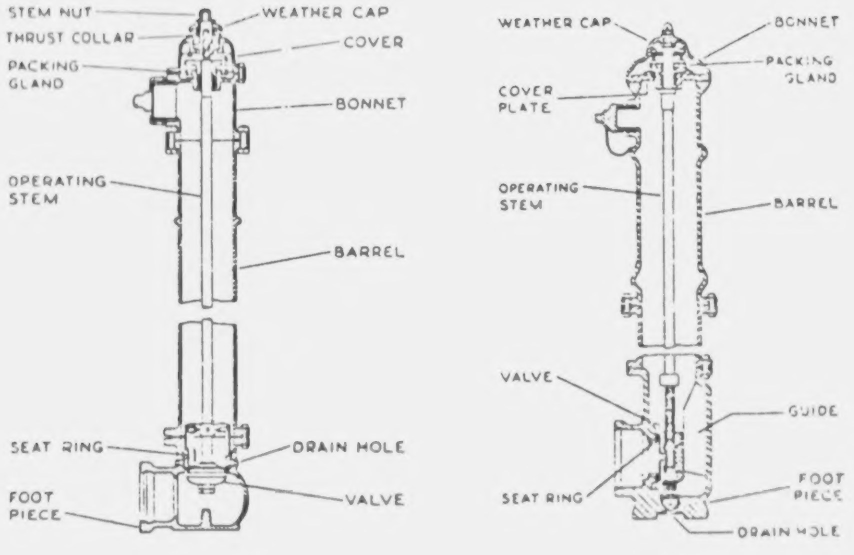
American B-62-B hydrants can be furnished as a TRAFFIC type by the use of frangible bolts at the flange joint above the ground line. Should the hydrant be damaged by traffic, new bolts, rod coupling and gasket would be the only parts necessary to place the hydrant back into service.



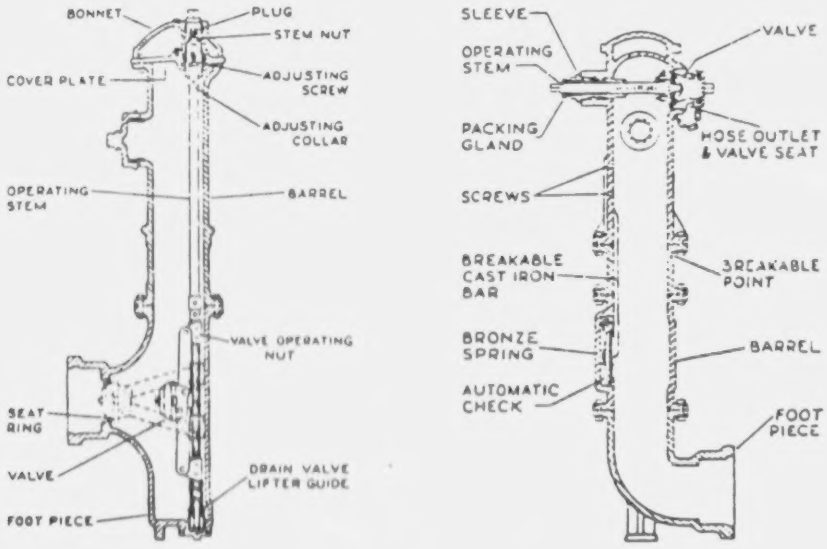
Fully complies with AWWA C-502.

Fig. 3.55 Typical fire hydrant

(Permission of American Valve and Hydrant, A Division of American Cast Iron Pipe Company)


STEM NUT
WEATHER CAP
THRUST COLLAR
COVER
PACKING GLAND
BONNET
OPERATING STEM
BARREL
SEAT RING
DRAIN HOLE
FOOT PIECE
VALVE
WEATHER CAP
BONNET
PACKING GLAND
COVER PLATE
OPERATING STEM
BARREL
VALVE
GUIDE
SEAT RING
FOOT PIECE
DRAIN HOLE

CENTER STEM GATE


BONNET
PLUG
STEM NUT
COVER PLATE
ADJUSTING SCREW
ADJUSTING COLLAR
OPERATING STEM
BARREL
VALVE OPERATING NUT
SEAT RING
VALVE
DRAIN VALVE LIFTER GUIDE
FOOT PIECE
SLEEVE
VALVE
OPERATING STEM
PACKING GLAND
HOSE OUTLET & VALVE SEAT
SCREWS
BREAKABLE CAST IRON BAR
BREAKABLE POINT
BRONZE SPRING
BARREL
AUTOMATIC CHECK
FOOT PIECE

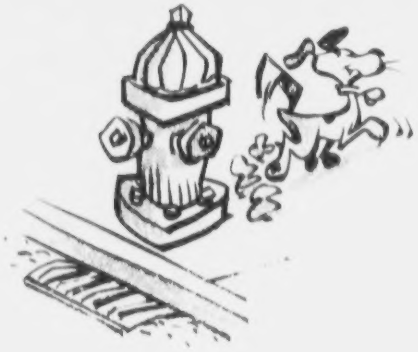
COREY WET-BARREL

Fig. 3.56 Hydrant types

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

valve and stem out of the barrel by removing the head. A shutoff valve should be provided on every hydrant lateral. Traffic safety is taken into account in the design of some barrels which have a breakaway point in case the hydrant is struck by a vehicle. If the barrel is broken, the valve stem is also designed to break.

Fire hydrants should not be more than 500 feet (150 m) apart to avoid excessive friction head loss in fire hoses. They are usually located much closer together in high value (business and commercial) districts. Preferably, they should be placed at intersections so they can be used in all directions from the corner.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.67L List the uses of fittings.

3.67M List the uses of hydrants.

3.67N What are the four major parts of a hydrant?

End of Lesson 4 of 5 on DISTRIBUTION SYSTEM FACILITIES

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 4 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 3.

18. Why are wet taps preferred over dry taps on water distribution lines?
19. List the purposes valves may be used for in a water distribution system?
20. Surge pressures in water systems can be caused by what activities?
21. How can air vacuum and pressure relief valves be protected against possible contamination?
22. What safety precautions should be taken before entering a deep valve vault?

CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 5 of 5 Lessons)

3.7 METERS

3.70 Purpose of Meters

The primary function of a meter is to measure and display the amount of water passing through it. A metered water system is one in which meters are used at all strategic points: on main supply lines, pumping stations, reservoir outlets, connections to other utility systems, and at each customer's service. Metering provides many benefits. The customer can be billed for the exact amount of water used, the amount of water produced can be determined, losses of water can be detected by comparing service meter and hydrant use meter readings with production meter readings, and capacities of pipelines can be determined. By determining costs, metering prevents waste through excessive use of water and thereby reduces water consumption. Meters are also used to provide accurate blending of waters of different quality so that the mix in the reservoirs is of the same constant quality. The information obtained from metering can show how efficient the water utility is operating and can provide for system control.

3.71 Meter Selection

In selecting meters, look for the ability to measure and register your anticipated flow levels, ability to meet required capacity with minimum head loss, durability, ruggedness, precision of workmanship, ease of repair, availability of spare parts, freedom from irritating noise, a reasonable price, and a manufacturer with a good reputation. When selecting a brand of water meter for your utility, be sure to consider the availability of replacement meters and spare parts. Also try to determine the delivery time for the manufacturer to respond to an order for a needed part. Check with other utilities to verify that the manufacturer has the kind of warranty you want and will stand behind its products.

Sufficient accuracy is needed so that small meters do not register less than 98.5 percent nor more than 101.5 percent of the water passing through them. Large meters should accurately measure between 97 and 103 percent. Certain large meters are accurate within 1 percent. Generally, meters of 1 inch (25 mm) and smaller should have a head loss not exceeding 15 psi (103 kPa or kg/sq cm), while the head loss of larger meters should not exceed 20 psi (138 kPa or 1.4 kg/sq cm).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.7A At what strategic points should meters be used?

3.7B How does metering reduce water consumption?

3.7C List the important qualities you would look for when selecting a meter.

3.7D Calculate the head loss through a meter in feet if the pressure loss is 15 psi (1 psi = 2.31 ft).

3.72 Meter Types

Basically, meters can be classified as small-flow meters, large-flow meters, and combination large-small flow meters as shown below.

I. Small Flow Meters (Displacement Type)
  A. Nutating-Disc
  B. Piston

II. Large Flow Meters (Velocity Type)
  A. Turbine
  B. Propeller
  C. Venturi
  D. Electronic
  E. Insertion

III. Combination Meters (Compound Type)

3.720 Displacement Meters

Displacement-type meters are small-diameter meters commonly used for customer services which go up to two inches (50 mm) in size but may, for commercial services, be as large as six inches (15mm) (Figure 3.57). This type of meter measures the flow by registerig the number of times the meter chamber, whose volume is known, is filled and emptied. In this chamber, which is usually cylindrical in shape, a piston or disc goes through a certain cycle of motion that corresponds to a single filling and emptying of the chamber. This movement is transferred to a register.

The advantages of displacement meters are that they can measure wide variations of flow rate within their rated capacity and, in sizes up to two inches (50 mm), are accurate in registering low flows. The principal limitations are that in sizes greater than two inches (50 mm), the sensitivity at the lower rate of flow decreases so much that it is advisable to use another type of meter. Their capacity is limited and at high flows there is a high head loss. Also, large quantities of foreign matter or corrosion will either stop the meter entirely or cause its accuracy to decrease because of friction.

The different ways in which the disc or piston in the displacement meter moves have been used to categorize the various types of displacement meters. The two types normally encountered are the nutating-disc and the piston meters.

The nutating-disc meter is the most commonly used meter on small-diameter domestic services (Figures 3.57 and 3.58). Nutating means nodding, which somewhat describes the action of the disc in the chamber of the meter. The disc may be flat or conical in shape and is made of hard rubber. When water flows, the tilted disc rotates. These meters are made with a bottom plate which breaks away automatically to prevent damage when the water freezes.

In the piston-type meter, water flows into a chamber and displaces a piston and the oscillatory circulating motion is transmitted to a register (Figure 3.59). Piston-type meters have a slightly greater head loss than in the nutating-disc meter.

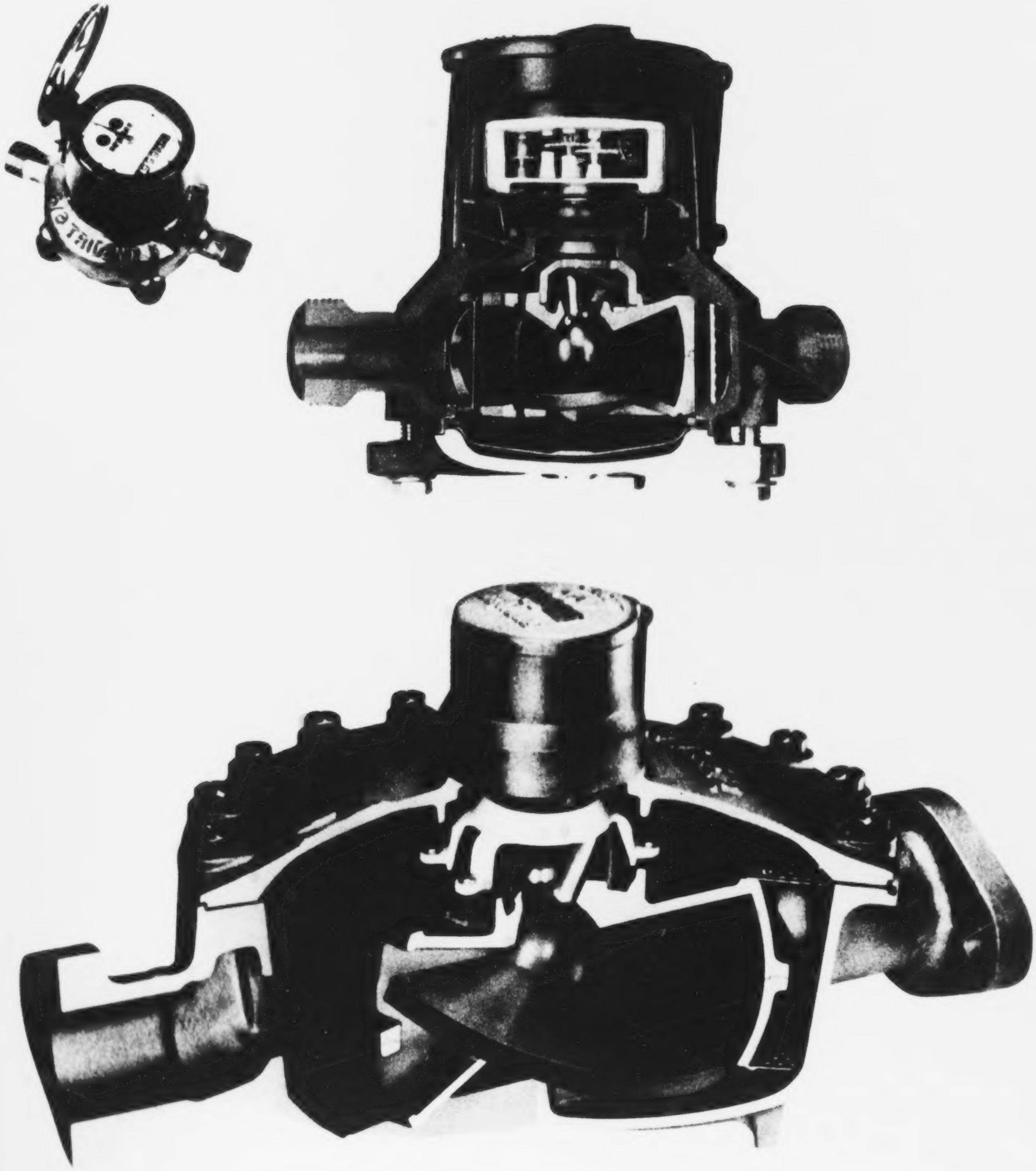


Fig. 3.57 Nutating (nodding)-disc water meters

(Permission of Neptune Water Meter Company)

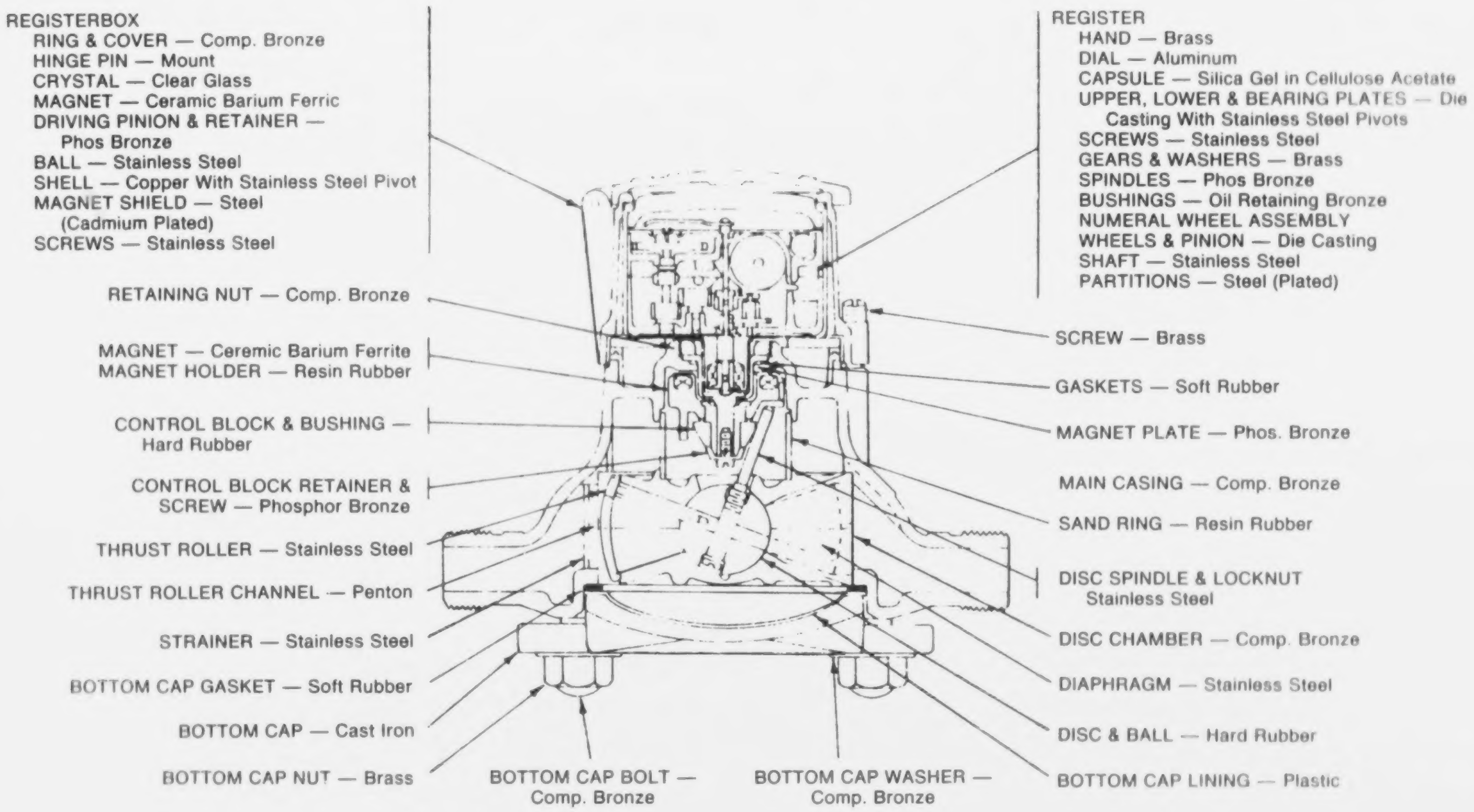

REGISTERBOX
RING & COVER — Comp. Bronze
HINGE PIN — Mount
CRYSTAL — Clear Glass
MAGNET — Ceramic Barium Ferric
DRIVING PINION & RETAINER — Phos Bronze
BALL — Stainless Steel
SHELL — Copper With Stainless Steel Pivot
MAGNET SHIELD — Steel (Cadmium Plated)
SCREWS — Stainless Steel
RETAINING NUT — Comp. Bronze
MAGNET — Ceremic Barium Ferrite
MAGNET HOLDER — Resin Rubber
CONTROL BLOCK & BUSHING — Hard Rubber
CONTROL BLOCK RETAINER & SCREW — Phosphor Bronze
THRUST ROLLER — Stainless Steel
THRUST ROLLER CHANNEL — Penton
STRAINER — Stainless Steel
BOTTOM CAP GASKET — Soft Rubber
BOTTOM CAP — Cast Iron
BOTTOM CAP NUT — Brass
BOTTOM CAP BOLT — Comp. Bronze
BOTTOM CAP WASHER — Comp. Bronze
REGISTER
HAND — Brass
DIAL — Aluminum
CAPSULE — Silica Gel in Cellulose Acetate
UPPER, LOWER & BEARING PLATES — Die Casting With Stainless Steel Pivots
SCREWS — Stainless Steel
GEARS & WASHERS — Brass
SPINDLES — Phos Bronze
BUSHINGS — Oil Retaining Bronze
NUMERAL WHEEL ASSEMBLY
WHEELS & PINION — Die Casting
SHAFT — Stainless Steel
PARTITIONS — Steel (Plated)
SCREW — Brass
GASKETS — Soft Rubber
MAGNET PLATE — Phos. Bronze
MAIN CASING — Comp. Bronze
SAND RING — Resin Rubber
DISC SPINDLE & LOCKNUT Stainless Steel
DISC CHAMBER — Comp. Bronze
DIAPHRAGM — Stainless Steel
DISC & BALL — Hard Rubber
BOTTOM CAP LINING — Plastic

Fig. 3.58 Section view of nutating-disc meter

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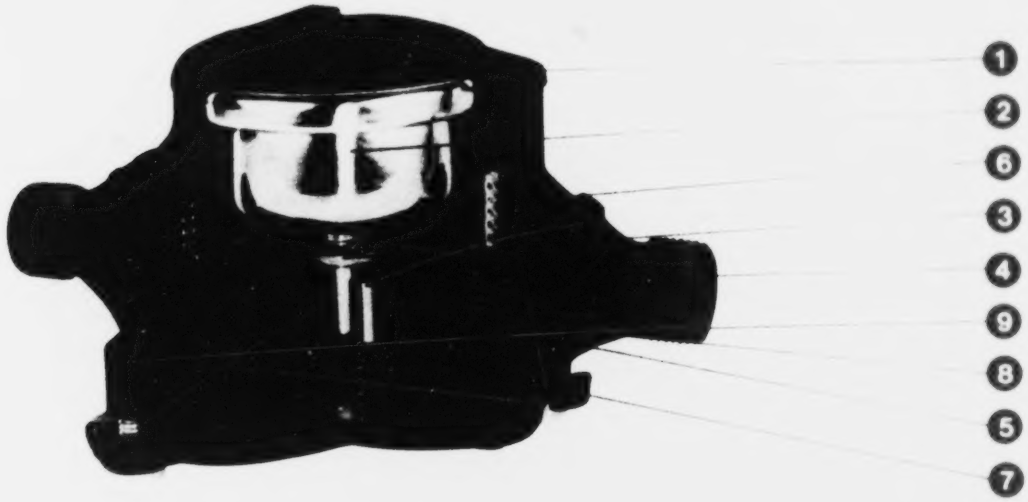


1. Heat treated glass
2. Hermetically-sealed register
3. Register retainer
4. Magnetic drive
5. Oscillating piston and piston roller
6. Cylindrical strainer
7. Interchangeable bottom plate
8. Measuring chamber
9. All cast bronze maincase

Fig. 3.59 Piston-type meter

(Courtesy of Rockwell International Corporation, Municipal & Utility Division)

3.721 Velocity-Type Meters

These meters are sometimes called current meters. They are found in sizes up to 36 inches (900 mm) and larger and actually measure the velocity of flow past a cross section of known area. Large quantities of water (within meter capacity) can be passed without any damage to their working parts and the meters are rugged and easy to maintain. Their rather low head loss is ideal for a meter that must pass high rates of flow; however, the meters become unreliable at low flow rates. Some low flows will pass through without being registered at all. This kind of meter is very satisfactory for main lines, pumps with continuous high flow rates and irrigation, golf course, industrial and other high flow uses.

Velocity meters include turbine (Figures 3.60 and 3.61) and propeller meters (Figure 3.62), as well as the Venturi insertion type and most electonic water meters.

In turbine or propeller meters, the rotors or propellers are turned by the flow of the water at a speed proportional to the velocity of water flow. This movement is then transmitted to a register. They are not designed for low flows or stop-and-go operation. Both types of meters are most useful in measuring continuously high flows, and both have low friction loss. The propeller meter may be installed within a section of pipe or it may be saddle mounted.

When main lines must be metered, it is desirable to have a meter that will not interfere with the flow of water if the meter fails. In case of fire, nothing must stop the effective flow of water. One principal type of meter that meets this requirement is the venturi meter which is shown in Figure 3.63. A venturi meter consists of an upstream reducer, a short throat piece, and a downstream expansion section which increases the diameter from the throat section to that of the downstream pipe. The amount of water passing through is metered by comparing the pressure at the throat and at a point upstream from the throat. Venturi meters are accurate over a large flow range and cause little friction loss.

An orifice plate can be used as an insertion-type meter. A thin plate with a circular hole in it is installed in the pipeline between a set of flanges (Figure 3.64). Flow is determined by comparing the upstream line pressure with the reduced pressure at the orifice restriction. Orifice plates are quite a bit less expensive than venturi meters, occupy less space, but have more severe pressure losses and are somewhat less reliable.

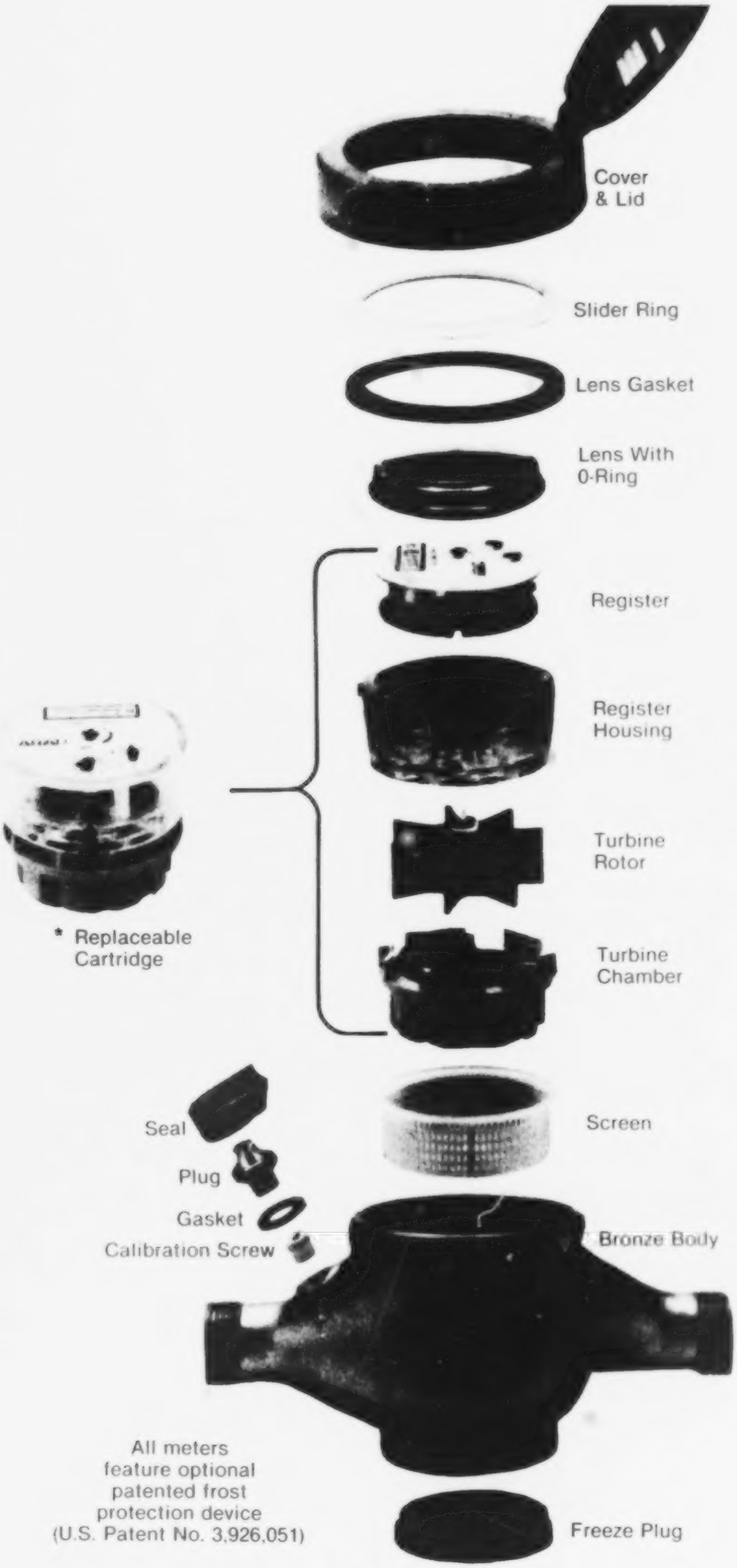
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.7E What is the major difference between small-flow meters and large-flow meters?

3.7F List the two types of displacement meters.

3.7G List the types of velocity meters.


Cover
& Lid
Slider Ring
Lens Gasket
Lens With
0-Ring
Register
Register
Housing
Turbine
Rotor
Turbine
Chamber
* Replaceable
Cartridge
Seal
Plug
Gasket
Calibration Screw
Screen
Bronze Body
Freeze Plug

All meters
feature optional
patented frost
protection device
(U.S. Patent No. 3,926,051)

Fig. 3.60 Turbine water meter
(Permission of Neptune Water Meter Company)

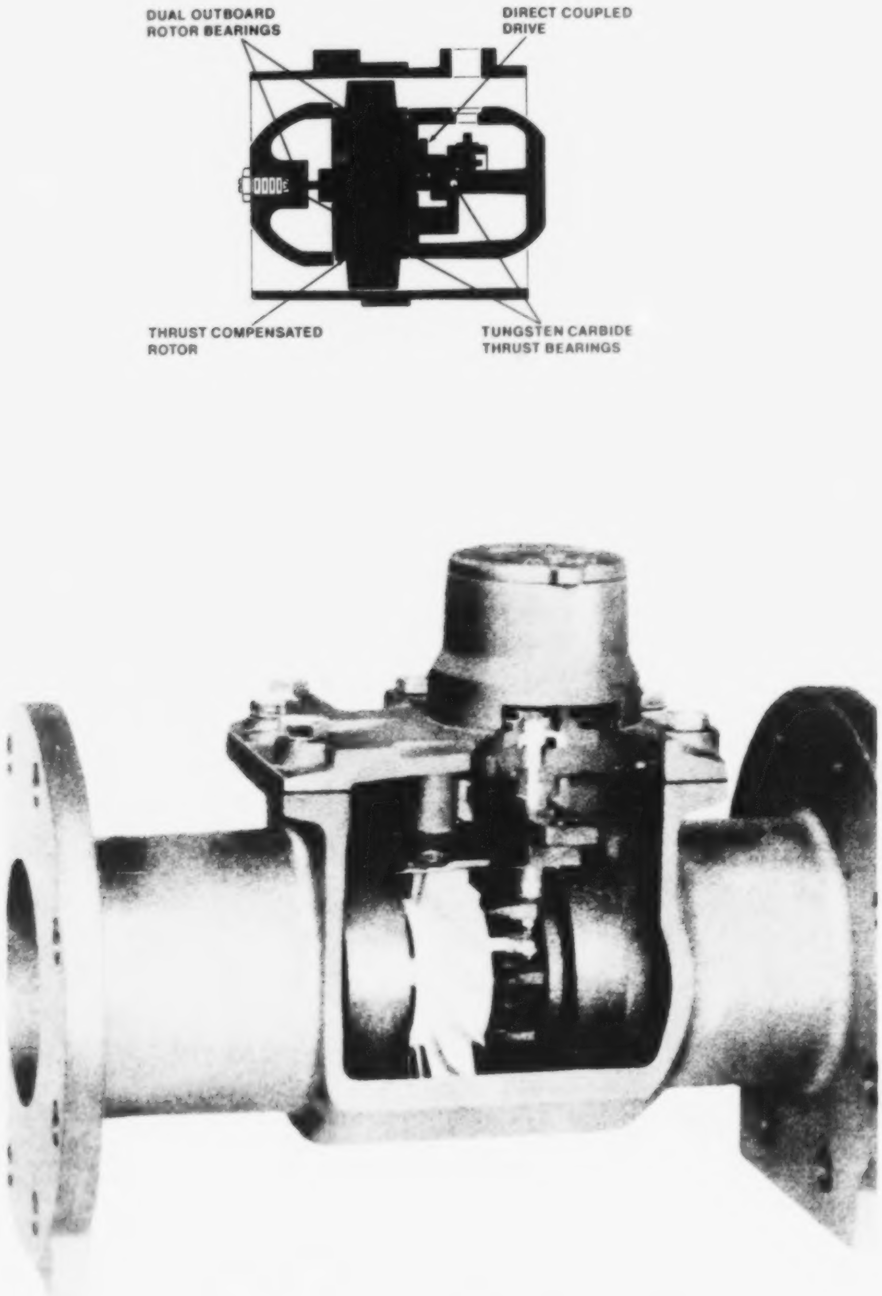

DUAL OUTBOARD ROTOR BEARINGS
DIRECT COUPLED DRIVE
THRUST COMPENSATED ROTOR
TUNGSTEN CARBIDE THRUST BEARINGS

Fig. 3.61 Turbine water meter

(Permission of Western Water Meter)

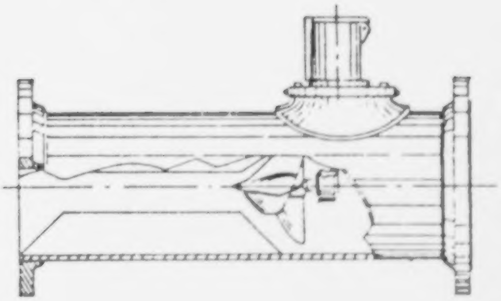


Fig. 3.62 Propeller meter

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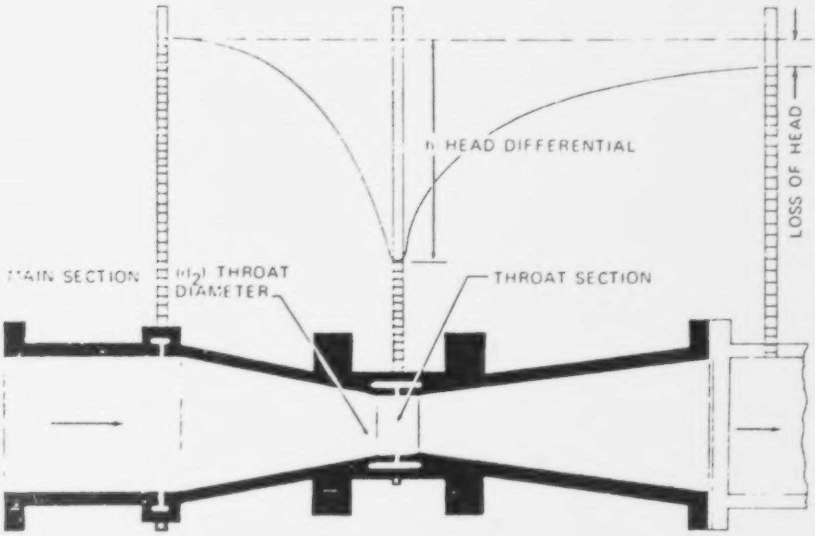
h HEAD DIFFERENTIAL
LOSS OF HEAD
MAIN SECTION
(d_2) THROAT DIAMETER
THROAT SECTION

Fig. 3.63 Venturi meter

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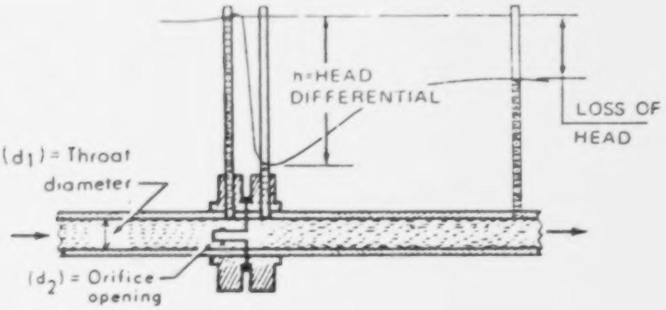
h=HEAD DIFFERENTIAL
LOSS OF HEAD
(d_1) = Throat diameter
(d_2) = Orifice opening

Fig. 3.64 Orifice-plate meter

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3.722 Compound Meters

When water flow fluctuates widely, a compromise between the low and high-flow meters is used. This compromise is a combination of the displacement and velocity-type meters and is called a compound meter. The displacement part of the meter records the low flows, and when the head loss through this part of the meter rises to a certain level, a compounding valve is actuated and permits the water to flow through the velocity portion of the meter. Compound meters are shown in Figures 3.65, 3.66 and 3.67.

Compound meters have special advantages in places where there are predominantly low or intermediate flows and only occasional high flows. This would include services to hotels, hospitals, factories, schools, apartment houses, commercial properties, and office buildings. They are best suited for locations with widely varying flows where accurate low-flow measurement is needed. However, where the majority of flows are moderate to high, a turbine meter is generally used.

The main advantage of compound meters, with the separate measuring chambers, is that they accurately measure flows from a fraction of a gallon up to the normal capacity of the pipeline. Even very small flows from leaks and individual faucets can be measured accurately. Compound meters can be subjected to high rates of flow for long time periods and are more rugged than displacement meters. Their limitations are that loss of head from friction is higher than in large-flow meters; during the changeover from low to high and high to low flows their accuracy drops; and they are large, cumbersome, and expensive.

3.723 Electronic Meters

Electronic meters include the magnetic and sonic types of meters. The magnetic meter is often called a "mag meter." Water flowing through a magnetic field induces a small electric current flow which is proportional to the water flow. The electric current produced is measured and mathematically changed to a measure of water flow.

Sonic meters contain sensors which are attached to the sides of a pipe. Sound pulses are sent alternately across the pipe in opposite diagonal directions. The frequency of the sound changes with the velocity of the water through which the sound waves must travel. An accurate measurement of water flow can be made using the difference between the frequency of the sound signal traveling with the flow of water and that traveling against the flow of water.

Electronic meters are generally highly accurate and there is no head loss. However, they are adversely affected by anything which distorts the velocity of the water flowing through the pipe such as elbows, pumps and certain types of valves. This condition can make the meters so inaccurate as to be practically useless. The problem can be corrected, though, by leaving a distance of at least ten pipe diameters between an upstream obstruction or fitting and the flow meter.

3.724 Proportional Meters

Another type of meter is the proportional meter in which a certain proportion of the total flow is diverted through a bypass meter and measured (Figure 3.68). The gears of the measuring bypass meter are adjusted to indicate on its register dial the total amount of water passing through the whole unit. The flows in the bypass line and the main pipe are proportional to the ratio of the areas of the bypass line and the main pipe. Therefore, a displacement or turbine meter which measures only the diverted flow can be calibrated to register the full amount of water in the main pipeline. The diversion of a portion of the flow through the bypass meter is accomplished by an orifice plate. This causes sufficient pressure differential to divert a portion of the water through the measuring meter. This type of meter is relatively accurate except for low flows. The meter is principally used to meter fire lines.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.7H Under what type of flow conditions are compound meters installed?

3.7I What are the two major types of electronic-flow meters?

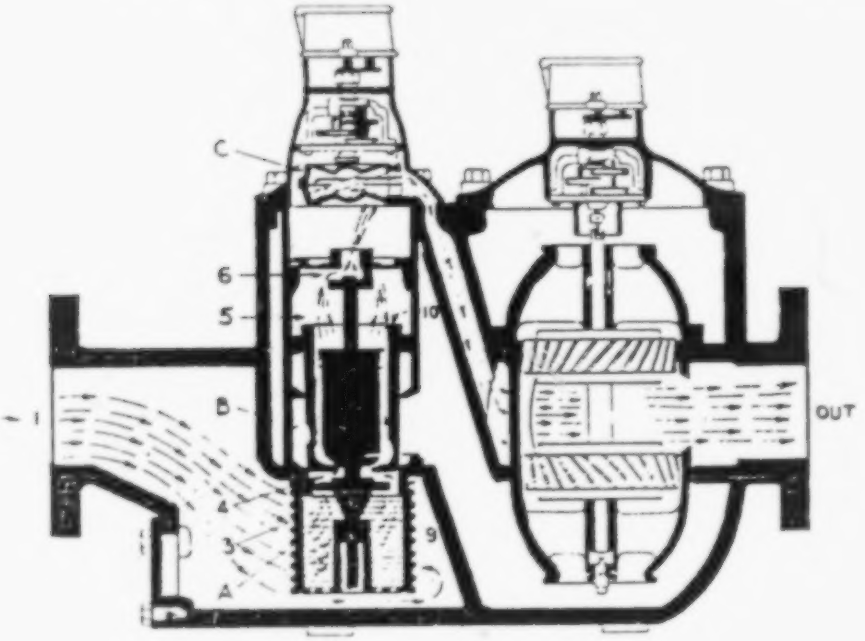
3.7J Fire lines may use what type of meter to measure flows?

3.8 CUSTOMER SERVICE

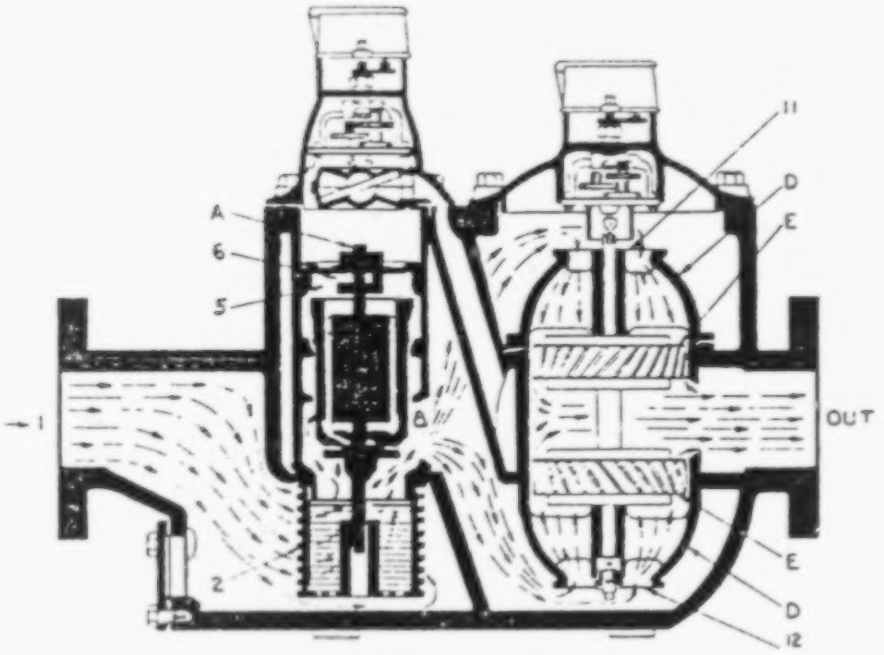
3.80 Installation

Typical service line installations are shown in Figure 3.69. In the top half of the figure (a) the installation includes a meter, while in the lower half (b) the meter is installed on the customer's premises or no meter is used. In cold climates the meter should be inside; however, the question of an inside versus an outside location of the meter is not as important as it once was because of the remote meter reading equipment that is available now.

The service line to the customer's system starts at the main with a corporation stop (shut-off valve) (see Figure 3.70). Various materials have been used for the service line including copper, plastic and galvanized or lined steel and iron pipe. Lead pipe has also been used, but is no longer acceptable due to its toxicity. Plastic pipe is frequently used for service lines. Copper pipe was popular until its price became too high. The service lines should be flexible. At its other end, the service line connects to another shut-off valve, the curb stop, which is attached to the meter. The meter is usually at the curb or property line. Finally, where a backflow contamination potential exists, backflow prevention devices are installed between the meter and the customer's line. Normally, the utility's responsibility for its service ends at the customer's side of the meter.


C
6
5
10
B
1
OUT
4
3
9
A

Low Flow


11
D
E
A
6
5
1
B
OUT
2
E
D
12

High Flow

Fig. 3.65 Flows through a compound meter

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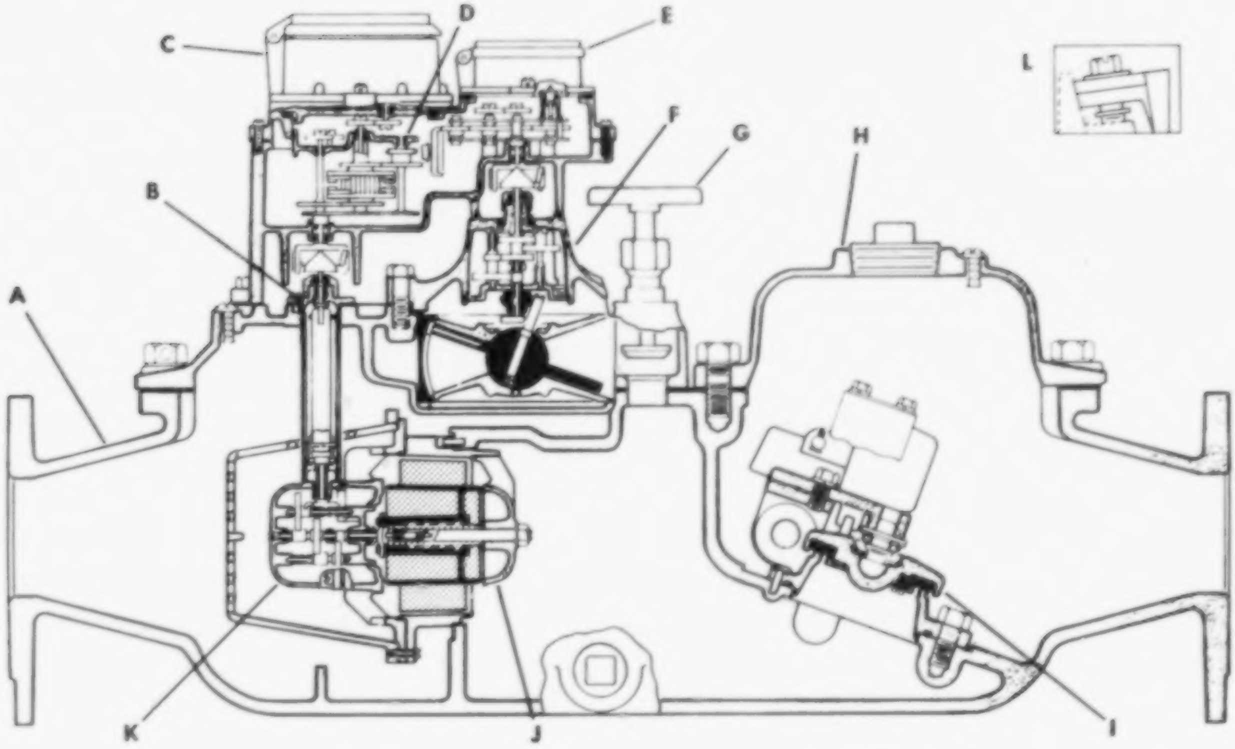
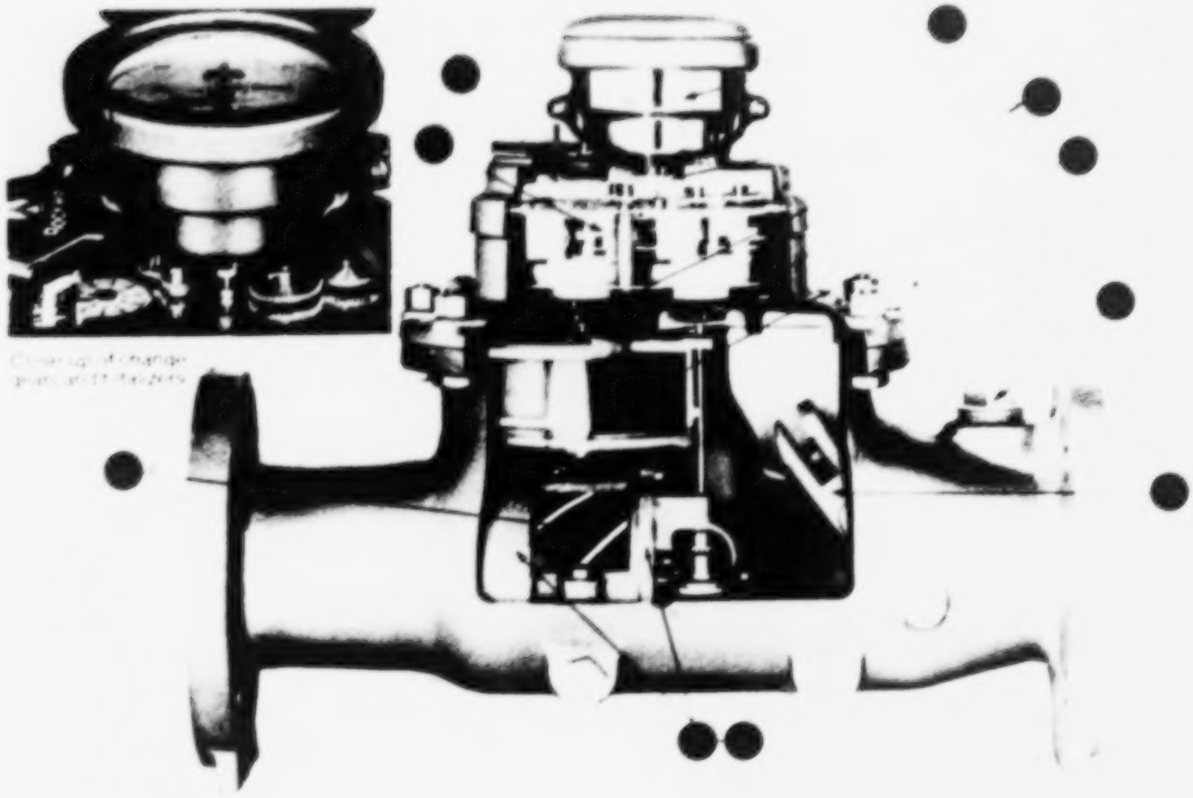


A. Main case	E. Test register & box	I. Valve
B. Stuffing box plate	F. Disc section	J. Measure wheel & cage
C. Register & box	G. Valve	K. Gear train
D. Combining drive	H. Cover	L. Clamps

Fig. 3.66 Sectional view of a compound meter

(Permission of Neptune Water Meter Company)



1. Totalizing register
2. By-pass chamber register
3. Magnetic couplings
4. Sealed coordinator module
5. By-pass chamber
6. Turbine chamber
7. Magnetic suspension
8. Roller bearings
9. Automatic swing check valve
10. Test plug

Fig. 3.67 Cutaway views of a compound meter
(Permission of Rockwell International)

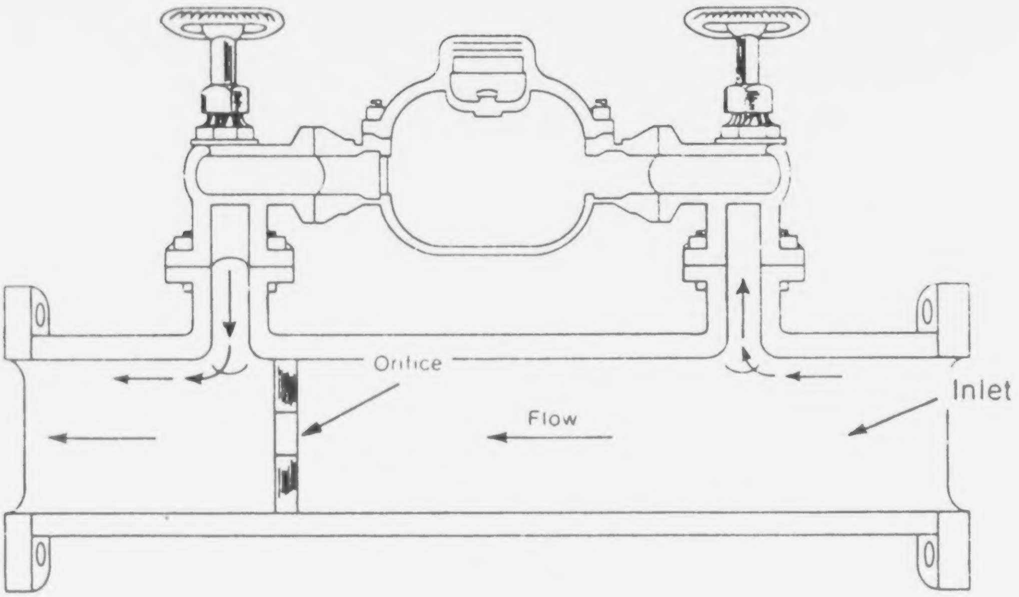

Orifice
Flow
Inlet

Fig. 3.68 Proportional meter

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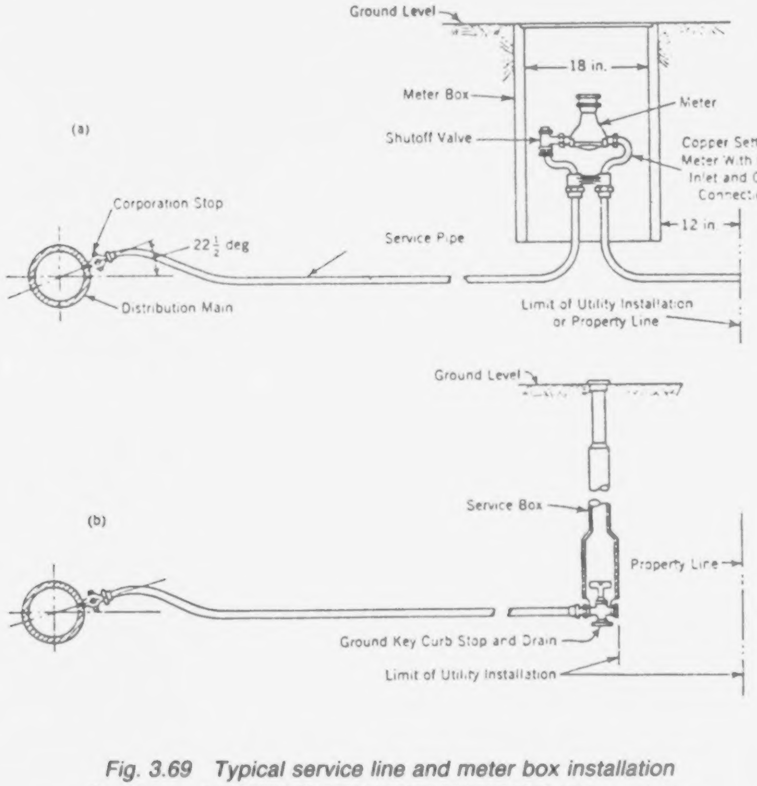
Ground Level
18 in.
Meter Box
Meter
(a)
Shutoff Valve
Copper Setting for Meter With Copper Inlet and Outlet Connections
Corporation Stop
22½ deg
Service Pipe
12 in.
Distribution Main
Limit of Utility Installation or Property Line
Ground Level
Service Box
(b)
Property Line
Ground Key Curb Stop and Drain
Limit of Utility Installation

Fig. 3.69 Typical service line and meter box installation

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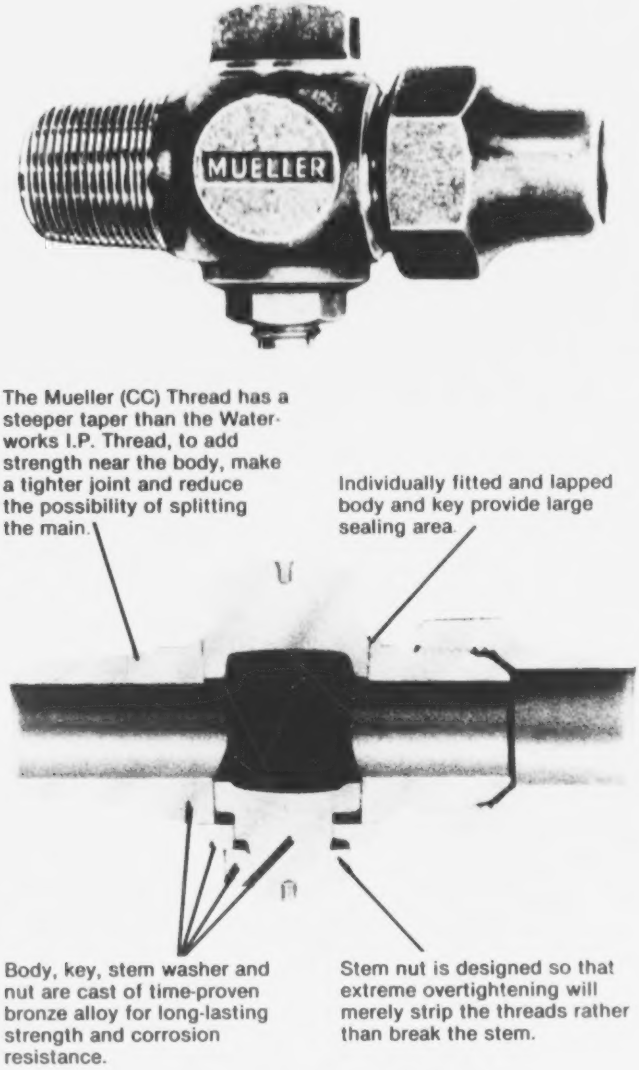

MUELLER
The Mueller (CC) Thread has a steeper taper than the Waterworks I.P. Thread, to add strength near the body, make a tighter joint and reduce the possibility of splitting the main.
Individually fitted and lapped body and key provide large sealing area.
Body, key, stem washer and nut are cast of time-proven bronze alloy for long-lasting strength and corrosion resistance.
Stem nut is designed so that extreme overtightening will merely strip the threads rather than break the stem.

Fig. 3.70 Corporation stop

(Permission of the Mueller Co. Mueller® Corporation Stops)

Service connections to the water main can be made at the time the main is installed or at any subsequent period. If a new service line is to be installed after the street is paved over, the buried main must first be found. This information is usually in the utility's records and maps. If it is not available, electronic detection instruments are used. When the main is located, the pavement is cut and a narrow trench dug. Care should be taken in properly bedding and placing backfill material over the pipe to prevent any possible damage.

Another method for installing the service line is to use a mole for tunneling through the soil. This is a device shaped like an artillery shell that is activated by compressed air and tunnels through almost any kind of soil. The pipe to be installed is attached to the back of the mole and compressed air is fed through the pipe into the mole. This assembly is not easy to direct and steer. In some soils, a pipe pusher can be used to force pipe up to 4 inches (100 mm) in diameter for a distance of 50 to 150 feet (15 to 45 m). If an existing service line is being replaced, the new line is attached to the old one and the whole assembly is pulled through with a back hoe or some other piece of motorized equipment.

3.81 Meters

The basic requirements of an acceptable meter installation, as recommended by the AWWA, are (1) that it be leak-tight, (2) that it provide an upstream shutoff valve of high quality and with low pressure loss, (3) that it position the meter in a horizontal plane for optimum performance, (4) that it be reasonably accessible for service and inspection, (5) that it provide for easy reading either directly or via a remote-reading device, (6) that it be reasonably well protected against frost, mechanical damage, and tampering, and (7) that it not be an obstacle, or hazard, to customer or public safety. Mechanical damage can usually be avoided by placing the meter behind the curb and in a meter box. The meter box may be made of concrete, cast iron or plastic. If it is plastic, metal particles are added to the plastic to facilitate locating a buried meter box if, by chance, maps and records should be lost or inaccurate. Additional protection can be provided by setting the meter in a copper yoke which connects rigidly and permanently the inlet and outlet pipes at the points where the meter is connected to them. This assures proper spacing and alignment of the meter, cushions the meter against stresses and strains in the piping and provides pipe support and electrical continuity if the meter is removed.

3.82 Meter Size

Meter selection and sizing can be more important to a system than all the meter repairs that follow. If the meter is not sized properly, it can be costly in repairs as well as in revenue lost for as long as that meter is in service. There is no hard and fast rule for selecting the right size meter. Factors that are taken into consideration are the range of flow rates; pressure at the service connection, differences in elevation between the street main and the highest water fixtures in the building to be served; and friction losses in the service line, meter, any backflow prevention devices installed, and in the house plumbing. A rule of thumb is that the meter should be one size smaller than the service line. In most residential services, a ¾-inch (18 mm) will be sufficient.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 153.

3.8A What is a corporation stop?

3.8B What is a curb stop?

3.8C How can mechanical damage of meters be avoided?

3.83 Backflow Prevention Devices

Backflow prevention devices, when used, are normally installed at the service connection directly downstream from the meter. Their purpose is, as indicated, to prevent backflow — the reverse flow of water of questionable quality from an unapproved water supply into a potable water system. Backflow may be caused by backpressure or backsiphonage, both of which result from a pressure differential. Backpressure results from a higher pressure in the unapproved water supply than in the domestic system, while backsiphonage takes place where there is a negative or reduced pressure in the domestic system.

Three basic backflow prevention devices are approved for use at service connections: (1) the double check valve assembly (Figure 3.71), (2) the reduced pressure principle (RP) device (Figure 3.71) and (3) the air-gap devices. Double check valves provide the least degree of protection, while an air-gap device provides the highest degree. The type of device required depends on the degree of hazard and the probability of backflow occurring. The complexity of the piping on the premises and how difficult it is to modify the system are also important.

All devices should be located on the user's side of the service and as close to the user connection as is practical. The double check valve assembly and the reduced pressure (RP) device have two check valves because the failure rate of a single check valve is much too high for reliable protection. The two check valves must be tested periodically and test cocks on the devices are required for this purpose. The devices must be installed where they are fairly accessible for testing and at least 12 inches (300 mm) above ground. If these devices are installed in a vault or a building, an adequate drain is required. Also they may not be enclosed so leaks and malfunctions can be easily observed. A double check valve and reduced pressure (RP) device installations are shown in Figure 3.72 and an air-gap separation installation is shown in Figure 3.73.

The double check valve assembly (Figure 3.74) consists of two internally loaded, independently acting check valves, located between two tightly closing shut-off valves. Four test cocks are included in the assembly. The operation of the check valves under normal flow conditions and under backflow conditions is illustrated in Figure 3.75. The pressure of the incoming water keeps the check valves open, but when the on-premise pressure gets higher than the water system pressure, the check valves shut tight and prevent backflow. The relative location of the check valves, gate valves and test cocks is shown in Figure 3.76. Check valves should be tested every three months.

The reduced pressure (RP) device is installed at services where dangerous materials are present on the premises or where a backflow situation is likely. This device is basically a double check valve assembly with a relief valve between the check valves. The device consists of two internally loaded check valves, an automatic differential relief valve located between the check valves, two shut-off valves and four test cocks.

In the event of back pressure (pressure downstream of the device increases and the direction of flow reverses), both check valves close and backflow is prevented. If there is leakage back into the zone between the two valves because the valves do not close tightly, the relief valve at the bottom opens and water is discharged to the atmosphere. If backsiphonage occurs with the supply pressure dropping to two psi (13.8 kPa or 0.14 kg/sq cm) or less, the relief valve will remain fully open. This will bring the pressure in the zone between the two check valves up to atmospheric pressure, thereby creating an air-gap between the two check valves. Figure 3.77 is a drawing showing the various parts of the reduced pressure (RP) device.

A properly designed air-gap installation provides the most positive type of backflow prevention available. A vertical gap between the end of the pipe discharge and the top of the receiving tank is created, with the gap being twice the diameter of the discharge pipe, but no shorter than one inch (25 mm). With this system there is no possibility of backflow and correct installation can be observed immediately. An acceptable air-gap separation installation is shown in Figure 3.73. All piping from the user connection to the receiving tank must be above grade and entirely visible unless the water supplier and health agency approve the burial of the line.

QUESTIONS

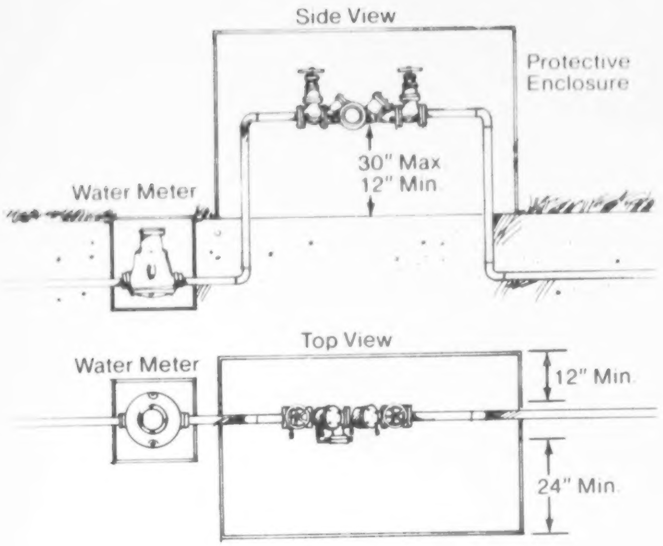
Write your answers in a notebook and then compare your answers with those on page 153.

3.8D Where are backflow prevention devices normally installed when used?

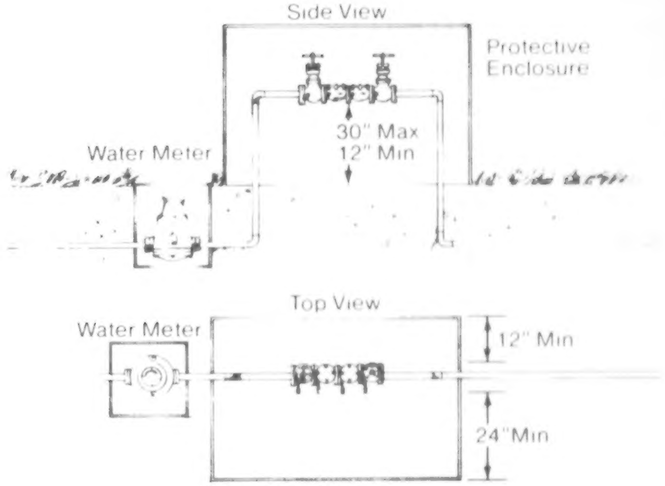
3.8E List the three basic backflow prevention devices that are approved for use at service connections.

3.8F Why are two check valves required for the double check valve assembly and the reduced pressure (RP) device?

3.8G What is the distance of the vertical gap in an air-gap device?


Side View
Protective Enclosure
30" Max
12" Min
Water Meter
Top View
Water Meter
12" Min
24" Min

Reduced pressure device


Side View
Protective Enclosure
30" Max
12" Min
Water Meter
Top View
Water Meter
12" Min
24" Min

Double check valve

NOTE: Protective enclosures are not used by some agencies so any leaks or malfunctions can be easily observed.

Fig. 3.71 Backflow prevention devices
(Permission of Febco)

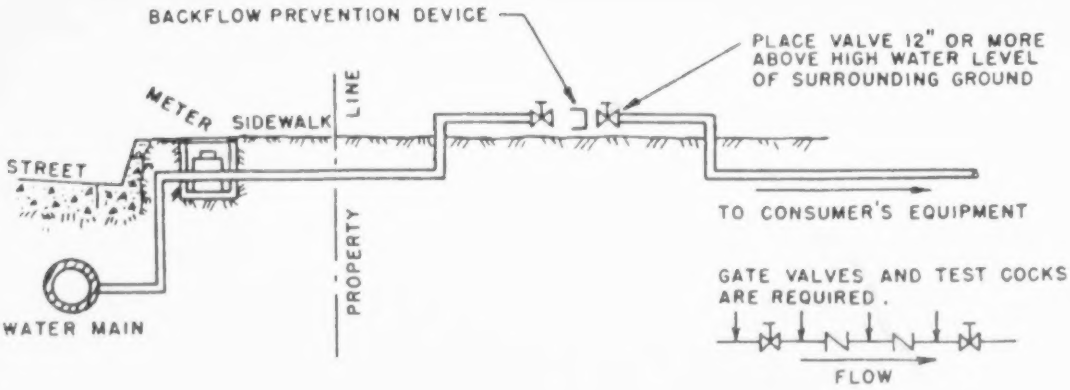

BACKFLOW PREVENTION DEVICE
PLACE VALVE 12" OR MORE ABOVE HIGH WATER LEVEL OF SURROUNDING GROUND
METER
SIDEWALK
PROPERTY LINE
STREET
WATER MAIN
TO CONSUMER'S EQUIPMENT
GATE VALVES AND TEST COCKS ARE REQUIRED.
FLOW

Fig. 3.72 Double check valve and RP device installation

(Permission of California Department of Health Services, Sanitary Engineering Branch)

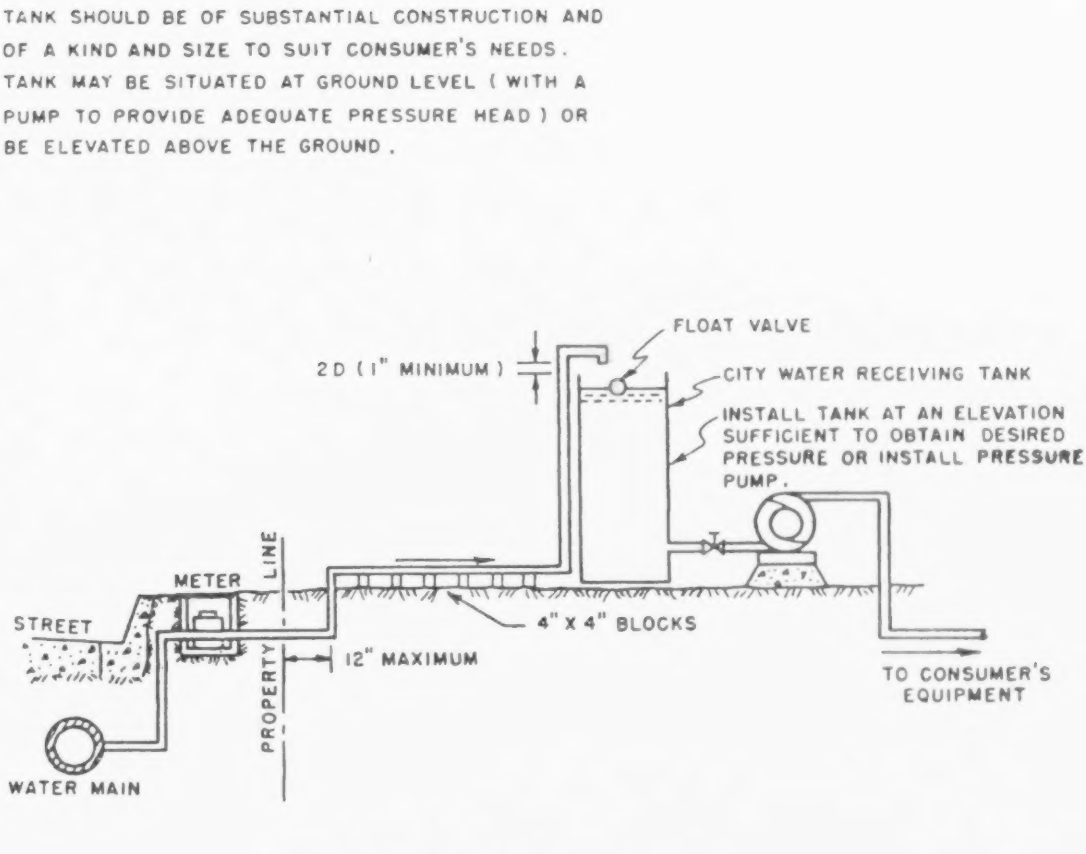
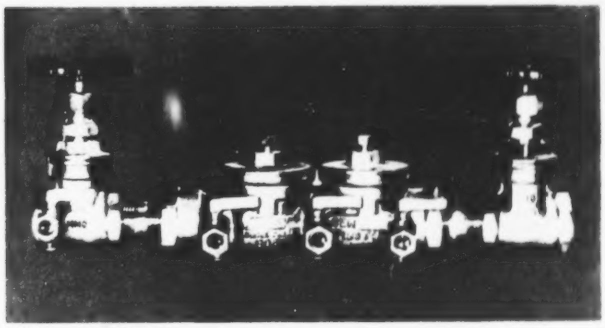
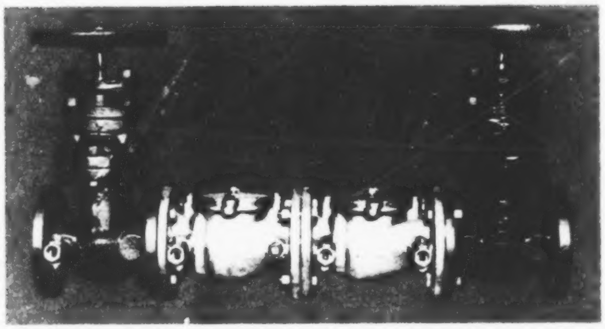

TANK SHOULD BE OF SUBSTANTIAL CONSTRUCTION AND OF A KIND AND SIZE TO SUIT CONSUMER'S NEEDS. TANK MAY BE SITUATED AT GROUND LEVEL (WITH A PUMP TO PROVIDE ADEQUATE PRESSURE HEAD) OR BE ELEVATED ABOVE THE GROUND.
FLOAT VALVE
2 D (1" MINIMUM)
CITY WATER RECEIVING TANK
INSTALL TANK AT AN ELEVATION SUFFICIENT TO OBTAIN DESIRED PRESSURE OR INSTALL PRESSURE PUMP.
METER
PROPERTY LINE
STREET
4" X 4" BLOCKS
12" MAXIMUM
TO CONSUMER'S EQUIPMENT
WATER MAIN

Fig. 3.73 Air-gap separation installation

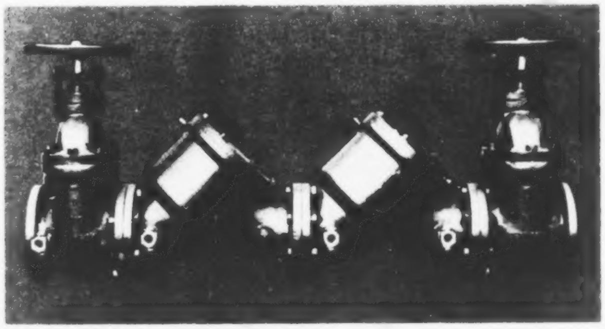
(Permission of California Department of Health Services, Sanitary Engineering)



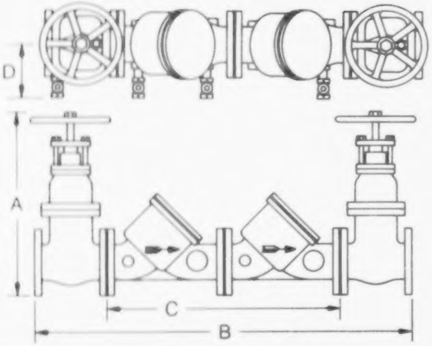
¾" through 2"

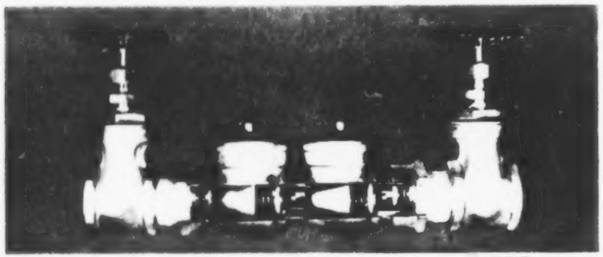


3" and 4"



6," 8" and 10"





2" Cutaway

Fig. 3.74 Double check valve unit

(Permission of Febco)

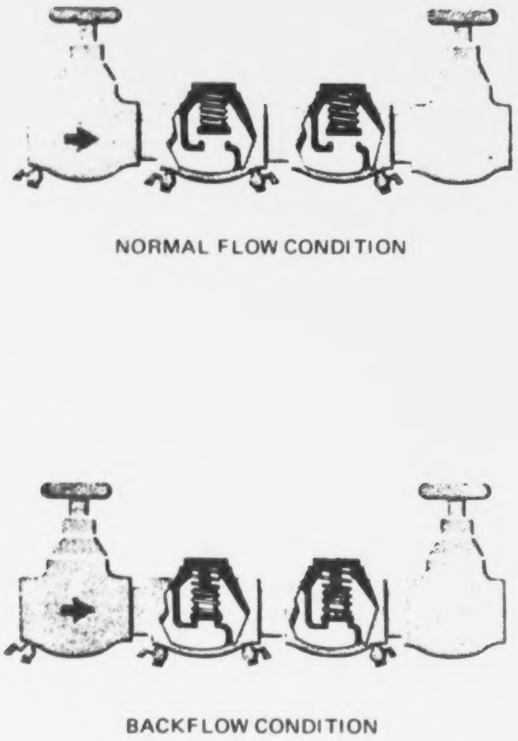

NORMAL FLOW CONDITION
BACKFLOW CONDITION

Fig. 3.75 Normal and backflow conditions
(Permission of Febco)

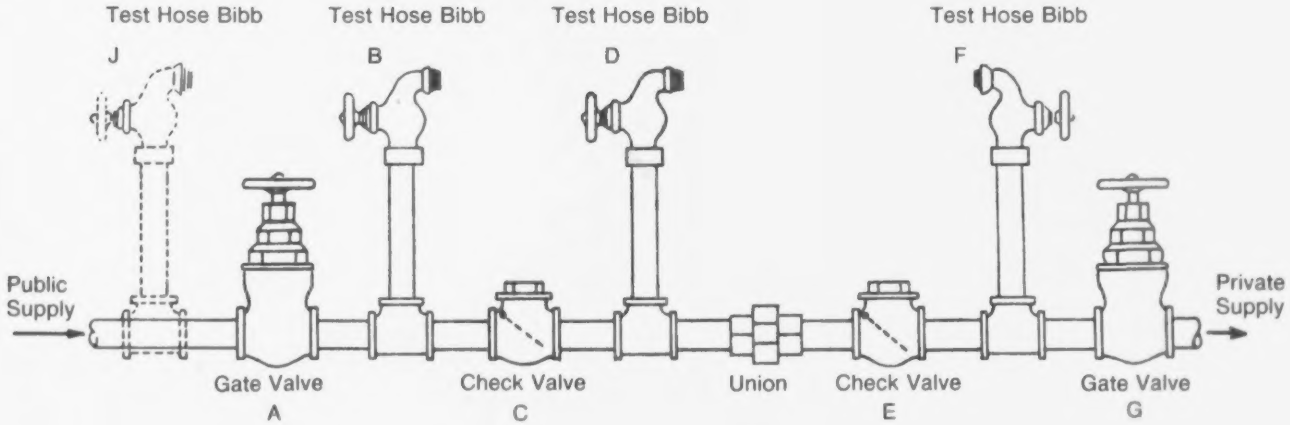
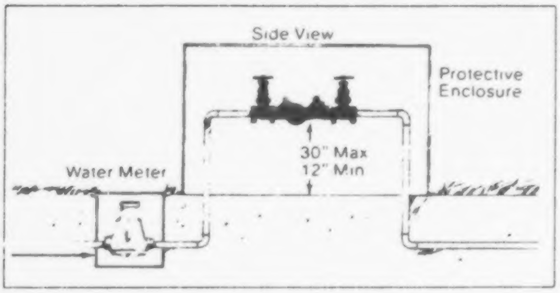
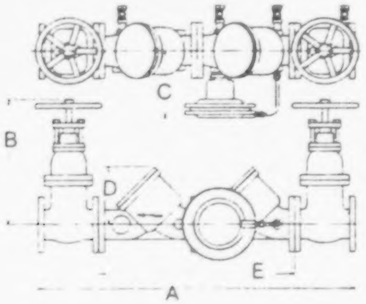

Test Hose Bibb
J
Test Hose Bibb
B
Test Hose Bibb
D
Test Hose Bibb
F
Public Supply
Private Supply
Gate Valve
A
Check Valve
C
Union
Check Valve
E
Gate Valve
G

Fig. 3.76 Method of testing check valves

Dimensions and Weights

Size	A	B	C	D	E	Wt./lbs.
1-1/2"	27-1/16"	7"	9"	5-3/4"	16-13/16"	90
2"	34-7/16"	12"	10"	6-1/4"	18-1/16"	136
2-1/2"	37-3/16"	12-1/2"	10-1/2"	7-1/2"	22-1/16"	280
3"	41-11/16"	14"	11-1/2"	8-1/16"	29-9/16"	285
4"	50-7/16"	17-3/8"	12-1/2"	11"	32-5/16"	460
6"	59-11/16"	21-1/4"	14"	14"	38-9/16"	775
8"	69-3/16"	26"	15"	18"	46-1/16"	1270
10"	84-3/16"	30"	16"	22"	58-1/16"	1720


Side View
Protective Enclosure
30" Max
12" Min
Water Meter



Approvals Model 825 1-1/2" — 10"

ASSE	USC	IAMPO	SBCC	CSA	UL*

*2-1/2" through 10"

Fig. 3.77 Reduced pressure backflow preventer

(Permission of Febco)

3.9 ARITHMETIC ASSIGNMENT

Turn to the Appendix at the back of this manual and read the following sections:

1. A.4 METRIC SYSTEM,
2. A.5 WEIGHT-VOLUME RELATIONS, and
3. A.6 FORCE, PRESSURE AND HEAD.

In Section A.13, Typical Water Distribution System Problems, read and work the problems in Sections A.130, Flows; A.131, Chemical Doses; and A.132, Distribution System Facilities.

Check all of the arithmetic in these sections on an electronic calculator. You should be able to get the same answers.

3.10 ADDITIONAL READING

1. *NEW YORK MANUAL*, Chapter 3, "Hydraulic and Electricity," and Chapter 17, "Protection of Treated Water."
2. *TEXAS MANUAL*, Chapter 15, "The Distribution System," and Chapter 17, "Customer Meters."
3. *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK.* Available from Computer Services. AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 20103. Price to members, $13.00; nonmembers, $16.50.
4. *A TRAINING COURSE IN WATER DISTRIBUTION (M8).* Available from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 30008. Price to members, $10.50; nonmembers, $13.00.
5. *INTRODUCTION TO WATER DISTRIBUTION.* Available from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 1916. Price $27.50.

End of Lesson
5 of 5 on
DISTRIBUTION
SYSTEM
FACILITIES

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

(Lesson 5 of 5 Lessons)

Write the answers to these questions in your notebook before continuing with the Objective Test on page 154. The problem numbering continues from Lesson 4.

23. Distribution system metering can provide what benefits?
24. What are the advantages and limitations of displacement meters?
25. List the major differences between an orifice plate and a venturi meter.
26. What are the advantages and limitations of electronic meters?
27. Why is the proper size of a meter important?
28. What causes backflow?
29. What factors are considered when selecting a backflow prevention device?

SUGGESTED ANSWERS

Chapter 3. DISTRIBUTION SYSTEM FACILITIES

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 62.

3.0A Water distribution systems consist of pipes, storage facilities, pumping stations, valves, fire hydrants, meters and other appurtenances.

3.0B A continuous positive water pressure must be maintained in the distribution system at all times so as to protect the distribution system from the entrance of toxic and other undesirable substances.

Answers to questions on page 69.

3.1A Excessive pressure may damage the customers' facilities and plumbing fixtures.

3.1B Friction losses in pipes are caused by the roughness of the inside of the pipe and the turbulence caused by the velocity of the flowing water.

3.1C Thrust can be caused at any point where water changes direction, increases velocity or the flow decreases or stops.

3.1D Water hammer can be caused by the action of pumps suddenly starting or stopping or valves quickly opening or closing.

3.1E

Known	**Unknown**
Pressure, psi = 30 psi	Pressure Head, ft

Calculate the pressure head in feet.

Pressure Head, ft = (Pressure, psi)(2.31 ft/psi)

= (30 psi)(2.31 ft/psi)

= 69 ft

Answers to questions on page 72.

3.2A The hydraulic adequacy of a distribution system is determined by the pressures that exist at various points in the system under the conditions of operation.

3.2B Booster pumps are installed directly on mains to increase the available system pressure.

3.2C Dead-end water mains should be avoided to prevent the development of taste and odor problems.

Answers to questions on page 73.

3.3A The requirements for operational storage can be reduced by the use of wells.

3.3B Concrete with a steel cylinder is commonly used for large water transmission mains.

Answers to questions on page 75.

3.4A Holding chlorinated water in covered distribution reservoirs provides an extended contact time for effective disinfection.

3.4B Distribution reservoir drains and overflows should have no cross-connections to any sewer line or other source of contamination and should be screened.

Answers to questions on page 76.

3.5A Centrifugal pumps are commonly used for water distribution systems.

3.5B Electric motors are the best source of power for distribution system pumps because they are compact and well adapted to automatic control or remote operation.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 78.

3.60A Dead-end water mains can cause taste and odor water quality problems.

3.60B Two advantages of grid or loop water distribution systems include (1) lack of dead ends and (2) a greater flow of water to an area when there is a fire or other source of high demand because water is being carried to any spot from more than one direction.

Answers to questions on page 78.

3.61A Water distribution system pipes must be capable of resisting forces from (1) backfill, (2) weight of passing traffic, and (3) internal water pressures such as delivery pressure, surges and water hammer.

3.61B Important installation features of water distribution pipes include weight, jointing characteristics, available sizes, and ease of tapping the line.

Answers to questions on page 80.

3.62A The external corrosion of ductile iron pipe can be reduced by the application of bituminous coatings.

3.62B Steel pipe may be lined with a bituminous material, cement mortar, or an epoxy.

3.62C Steel pipes may be coated with epoxy; they can be galvanized; or, a protective wrap could be used.

3.62D The major disadvantages of concrete pipe are that the pipe is heavy, may be hard to tap, needs special fittings and may deteriorate in aggressive (corrosive) soils.

Answers to questions on page 81.

3.62E The disadvantages of asbestos-cement pipe include its low flexural strength in small sizes, vulnerability to impact damage and difficulty in locating when buried and in using electrical thawing methods because the material is nonconductive.

3.62F Plastic pipe may be made of PVC (polyvinyl chloride), PE (polyethylene), and PB (polybutylene).

3.62G The most common materials used for service lines are copper, PVC, PE, PB, or, in special cases, reinforced plastic pipe.

3.62H Existing lead service lines should be replaced because of the potential for toxic lead to enter the water.

Answers to questions on page 87.

3.63A Basic requirements for a good pipe joint include a water-tight seal, easy installation, durability and corrosion-resistance.

3.63B Push-on and mechanical joints are most commonly used for ductile iron pipe. Flanged, restrained, flexible and sleeve joints are also used.

3.63C Steel pipe may be joined by bell and spigot lap welded joint, bell and spigot rubber gasket joint, harness joint, carnegie shape rubber gasket joint, butt welded joints, butt strap joint for welding, mechanically coupled joints and flanged joint for bolting.

Answers to questions on page 87.

3.63D The outside joint space is normally completely filled with cement mortar to protect the joint rings against external corrosion.

3.63E Couplings 3 to 12 inches (75 to 300 mm) in diameter allow five degrees deflection, and those with diameters from 14 to 24 inches (350 to 600 mm) permit a deflection of three degrees.

3.63F PVC pipe may be joined by solvent weld or bell and spigot joints.

Answers to questions on page 89.

3.64A The most commonly used corrosion control methods include (1) use of non-metallic materials (asbestos-cement, reinforced concrete, plastic), (2) non-metallic coatings, (3) metallic coatings, (4) chemical treatment, and (5) electrical control using cathodic protection.

3.64B Steel pipe can be protected from corrosion with cement mortar, cold-applied mastic, or hot coal tar enamel or, in the case of piping up to four inches in diameter, it can be galvanized.

ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 90.

3.65A Prior to excavating, all buried water, sewer, gas, power, telephone and cable TV lines, and storm drains in the work area should be located.

3.65B Water and sewer lines should be separated to avoid possible contamination of water if leakage from sewer lines saturates the soil in the vicinity of the water line. Critical conditions develop when the water main is depressurized and there is no pressure or a negative pressure. Contaminants in the saturated soil could be drawn into the water lines.

3.65C Metal pipe can be checked for damage by gently tapping each length with a hammer. If the pipe does not ring or hum clearly, the pipe has been damaged.

Answers to questions on page 96.

3.65D Trenches must be deep enough so that the pipe is protected from freezing, surface traffic, stream or river erosion, and possible future changes in the ground surface elevation.

3.65E Shoring requirements depend on depth of trench, width of trench, soil conditions, nearby activities and the laws and regulations.

3.65F Lack of shoring or shoring failure is the number one cause of cave-in deaths.

3.65G Shoring systems in trenches consist of some form of sheeting or liner, uprights held rigidly opposite each other against the trench walls by jacks or horizontal cross members (braces) and, if required, longitudinal members (stringers).

3.65H Uprights must extend as near to the bottom of the trench as permitted by the material being installed, but not more than two feet from the bottom.

Answers to questions on page 97.

3.65I All excavation work shall at all times be under the immediate supervision of someone with authority to modify the shoring system or work methods as necessary to provide adequate safety.

3.65J Spoils or excavated material must be placed two feet or more back from the edge of the trench. If the trench is over five feet deep, spoil must be placed more than four feet back from the edge of the trench.

3.65K All trenches deeper than 4 feet must be shored.

3.65L If shoring is not practical, the sides or walls of an excavation may be sloped.

3.65M Walkways must be provided for pedestrians to keep them out of the way of workers and to protect them from injury.

Answers to questions on page 97.

3.65N The different types of common shores include (1) hydraulic, (2) screw jacks, (3) air, (4) solid sheeting, (5) cylinder, and (6) shield.

3.65O The major concern during a shoring operation is the protection of the operators. Assume all trenches and excavations are unsafe.

Answers to questions on page 107.

3.65P Precautions that should be taken when laying pipe on bedding include being sure that the couplings do not rest on or settle down to the original trench bottom and also that the pipe is provided with even bedding for its entire length.

3.65Q When laying pipe with a bell, the bell should point in the direction that the work is proceeding, except that when the pipe is being laid downhill, the bell should face uphill.

3.65R Before joining pipes together, brush the inside of the pipe to remove any loose dirt and swab with a strong hypochlorite solution if necessary. Carefully clean the ends of the pipes and the joint materials and smooth out the rough edges.

3.65S Thrust blocks should be installed to prevent leakage or separation of joints at all tees, bends, caps, plugs, hydrants, and other fittings that change the direction of flow or stop the flow.

3.65T The first layer of backfill should be compacted up to the horizontal center of the pipe.

Answers to questions on page 110.

3.65U The leakage test pressure is at least 50 percent higher than the normal expected operating pressure or 150 psi, whichever is larger.

3.65V During grinding and polishing work on pipe, safety goggles must be worn.

ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 111.

3.66A In a wet tap, a valve is bolted to the tapping saddle and the actual drilling of the pipe through the valve is done with the pipe under pressure.

3.66B New service connections can be installed in existing plastic mains by using a drilling machine to drill into the main through a combined clamp and corporation stop.

Answers to questions on page 111.

3.67A Types of valves include gate valve, butterfly valve, ball valve, diaphragm valve and plug valve.

3.67B The main application of gate valves in water distribution systems is to isolate sections of mains to permit the making of emergency repairs without interruption of service to a large number of customers.

3.67C The two main uses of globe valves are flow and pressure regulation. Globe valves are also used to isolate sections of water mains.

Answers to questions on page 122.

3.67D Usually, pressure-regulating valves are of the globe design and have a spring-loaded diaphragm that adjusts the size of opening.

3.67E When air gets into water, the air tends to collect at high points in the lines. These air pockets can increase the resistance to flow by 10 to 15 percent, and it is even possible for an air-lock condition to occur and stop the flow of water completely.

3.67F Air relief valves (1) allow large quantities of air to escape during the filling of a pipeline, (2) permit air to enter a pipeline that is being drained, and (3) allow entrained air to escape while a line is operating under pressure.

3.67G Blow-off valves are used primarily for blowing off accumulated sediment from low spots in the line and for dewatering lines or reservoirs for repairs.

Answers to questions on page 123.

3.67H Valve boxes are installed to provide access to buried valves.

3.67I If a deep valve vault becomes flooded, a backsiphonage hazard could result.

3.67J Three valves should be installed at pipe crosses.

3.67K Valves may be operated manually, by water pressures (hydraulic or pneumatic), or electrically. Solenoids and electric motors geared to the valve mechanism are also used to open and close valves.

Answers to questions on page 130.

3.67L Fittings are used to connect pipes of the same size or different sizes, change the direction of flow, or stop the flow.

3.67M Hydrants are used for fire fighting, flushing of pipelines, and providing water to water trucks or other construction equipment.

3.67N The four major parts of a hydrant are (1) the inlet pipe connection from the water supply main, (2) the main valve, (3) the barrel and (4) the head.

ANSWERS TO QUESTIONS IN LESSON 5

Answers to questions on page 131.

3.7A Meters should be used on main supply lines, pumping stations, reservoir outlets, connections to other utility systems, and at each customer's service.

3.7B Metering reduces water consumption by determining costs and thus preventing waste through excessive use of water.

3.7C Important qualities to look for in a meter include ability to accurately measure and register your anticipated flow levels, ability to meet required capacity with minimum head loss, durability, ruggedness, precision of workmanship, ease of repair, availability of spare parts, freedom from irritating noise, a reasonable price, delivery time for spare parts, and a manufacturer with a good reputation.

3.7D

Known	**Unknown**
Head Loss, psi = 15 psi	Head Loss, ft

Convert the head loss from 15 psi to feet.

$$\begin{aligned} \text{Head Loss, ft} &= (\text{Head Loss, psi})(2.31\ \text{ft/psi}) \\ &= (15\ \text{psi})(2.31\ \text{ft/psi}) \\ &= 34.65\ \text{ft} \\ \text{or} &= 35\ \text{ft (approximately)} \end{aligned}$$

Answers to questions on page 134.

3.7E Small flow meters are of the displacement type and large flow meters are of the velocity type.

3.7F The two types of displacement meters are the piston and nutating-disc meters.

3.7G The types of velocity meters include turbine, propeller, venturi, insertion and electronic.

Answers to questions on page 138.

3.7H Compound meters are especially advantageous for places where there are predominately low or intermediate flows and, only occasionally, high flows.

3.7I The two major types of electronic-flow meters include the magnetic and sonic types of flow meters.

3.7J Proportional meters are used to measure flows in fire lines.

Answers to questions on page 144.

3.8A A corporation stop is a water service shutoff valve located at a street water main.

3.8B A curb stop is a water service shutoff valve located in a water service pipe near the curb and between the water main and the building.

3.8C Mechanical damage of meters can be avoided by placing the meter behind the curb and in a meter box.

Answers to questions on page 144.

3.8D Backflow prevention devices are normally installed at the service connection directly downstream from the meter.

3.8E The three basic backflow prevention devices are (1) the double check valve assembly, (2) the reduced pressure principle (RP) device, and (3) the air-gap device.

3.8F The double check valve assembly and the reduced pressure (RP) device have two check valves because the failure rate of a single check valve is much too high for reliable protection.

3.8G The distance of the vertical gap in an air-gap device between the end of the pipe discharge and the top of the receiving tank should be twice the diameter of the discharge pipe, but no shorter than one inch.

OBJECTIVE TEST

CHAPTER 3. DISTRIBUTION SYSTEM FACILITIES

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True — False

1. A positive water pressure in the distribution system is desirable to keep toxic substances out of the system.
   1. True
   2. False
2. Interior pipe roughness will increase over time.
   1. True
   2. False
3. The higher the C Factor, the smoother the inside of the pipe.
   1. True
   2. False
4. The hydraulic grade line always slopes downward towards an elevated service storage tank.
   1. True
   2. False
5. If water flows uphill in a water main, the hydraulic grade line will slope upward in the direction of the flow.
   1. True
   2. False
6. Energy savings result when storage tanks are filled during periods of high energy demand.
   1. True
   2. False
7. The total amount of water used per year for fire fighting is very small.
   1. True
   2. False
8. Distribution reservoirs should be located as close as possible to the centers of use.
   1. True
   2. False
9. Branching water distribution systems are most commonly found on the outskirts of a community.
   1. True
   2. False
10. Corrosion of ductile iron pipe can be caused by electrical currents flowing through water or moist soil.
    1. True
    2. False
11. Steel pipe is lighter than ductile iron pipe.
    1. True
    2. False
12. In the larger pipe sizes, concrete pipe is usually more expensive than any other kind of pipe.
    1. True
    2. False
13. When the push-on joint in ductile iron pipe is made in the field, the gasket is inserted into the flange.
    1. True
    2. False
14. Flanged joints are used because of their flexibility.
    1. True
    2. False
15. Cathodic protection is used to control corrosion of asbestos-cement pipe.
    1. True
    2. False
16. Lack of shoring or shoring failure are the major causes of underground construction deaths.
    1. True
    2. False
17. Water and sewer lines may be laid in the same trench to save money.
    1. True
    2. False
18. Before attempting to excavate for a water main, all utility companies should be notified.
    1. True
    2. False

19. Operators installing shoring always have to worry about cave-ins.
    1. True
    2. False

20. The AWWA has specifications for allowable leakage for different types of pipe during a leakage test.
    1. True
    2. False

21. When laying pipe with a bell on a downhill slope, the bell should face downhill.
    1. True
    2. False

22. Water mains can become contaminated during construction.
    1. True
    2. False

23. Valves are very important devices in water distribution systems.
    1. True
    2. False

24. Air relief valves are most effective when installed at low points in water mains.
    1. True
    2. False

25. Air and vacuum relief valves are usually combined in one unit.
    1. True
    2. False

26. Nutating-disc meters have a slightly greater head loss than piston-type meters.
    1. True
    2. False

27. A shutoff valve should be provided on every hydrant lateral.
    1. True
    2. False

28. Metal particles are added to the plastic in a meter box to facilitate locating buried meter boxes.
    1. True
    2. False

29. All water meters are practically useless when located immediately downstream from a pump due to inaccuracies caused by turbulent flow.
    1. True
    2. False

30. Air-gap devices provide the highest degree of backflow protection.
    1. True
    2. False

Multiple Choice

31. The minimum desirable pressure in a water distribution system is
    1. 15 psi.
    2. 20 psi.
    3. 25 psi.
    4. 30 psi.
    5. 35 psi.

32. Internal pipe roughness can be caused by
    1. Deposits in the pipe.
    2. Deterioration of the pipe.
    3. Pipe material.
    4. Poor manufacturing testing procedures.
    5. Rough handling during construction.

33. During a pressure test of a distribution system a pressure gage read 30 psi. What was the pressure head in feet?
    1. 13 ft
    2. 35 ft
    3. 69 ft
    4. 83 ft
    5. 92 ft

34. Large water transmission mains are commonly constructed of
    1. Concrete steel cylinder pipe.
    2. Copper pipe.
    3. Galvanized pipe.
    4. Plastic pipe.
    5. Zinc iron pipe.

35. Water level fluctuations in storage facilities controlling pressures in distribution systems are usually limited to
    1. 30 feet.
    2. 50 feet.
    3. 75 feet.
    4. 100 feet.
    5. 150 feet.

36. Distribution systems are expected to deliver
    1. Adequate pressure.
    2. Potable water.
    3. Sufficient water.
    4. Water of suitable quality.
    5. Water to fight fires.

37. Distribution reservoir capacity should be sufficient to meet
    1. Demands from unconnected water districts.
    2. Emergency reserve.
    3. Equalizing storage.
    4. Fire reserve.
    5. Operating storage.

38. Advantages of asbestos-cement pipe include
    1. Ease of location when buried.
    2. High flexural strength.
    3. Resistance to corrosion.
    4. Resistance to impact damage.
    5. Use of electrical thawing methods.

39. Water distribution mains are laid out in what types of systems?
    1. Branching
    2. Diamond
    3. Grid
    4. Loop
    5. Wishbone

40. The need for shoring and shoring requirements depends on
    1. Depth of trench.
    2. Nearby activities that could cause vibrations.
    3. Soil conditions (compaction, moisture).
    4. Type of soil (clay, loam, sand).
    5. Width of trench.

41. Types of trench shores include
    1. Air shores.
    2. Hydraulic shores.
    3. Screw jacks.
    4. Solid sheeting.
    5. Water shores.

42. Water mains should be installed at least ______ feet horizontally from sanitary sewers located parallel to the main.
    1. 1
    2. 5
    3. 8
    4. 10
    5. 15

43. Dresser and victualic couplings are commonly used with what pipe materials?
    1. Asbestos-cement
    2. Concrete
    3. Ductile iron
    4. Plastic
    5. Vitrified clay

44. The size of thrust blocks depends on the
    1. Size of pipe.
    2. Type of fitting.
    3. Type of soil.
    4. Type of water.
    5. Water pressure.

45. Thrust blocks should be installed to prevent
    1. Blocking of thrust.
    2. Corrosion.
    3. Separation of joints.
    4. Vehicles from causing accidents.
    5. Vibration of pumps.

46. Air can get into the water in distribution systems through
    1. Elevated tanks.
    2. Hydrants.
    3. Leaky joints.
    4. Packing glands.
    5. Pumps.

47. Valves may be used in water distribution systems to
    1. Blow off water.
    2. Prevent backflow.
    3. Prevent backsiphonage.
    4. Provide air relief.
    5. Reduce pressure.

48. The measuring accuracy of small water meters should read no less than ______ percent nor more than ______ percent of the water passing through them.
    1. 99.0 - 101.0
    2. 98.5 - 101.5
    3. 98.0 - 102.5
    4. 97.5 - 102.5
    5. 97.0 - 103.0

49. An elevated storage tank contains water 25-feet deep. What is the pressure on the bottom of the tank?
    1. 6 psi
    2. 11 psi
    3. 15 psi
    4. 25 psi
    5. 58 psi

50. Determine the upward force on the bottom of an empty underground storage tank caused by a groundwater depth of 4 feet above the tank bottom. The tank is 8-feet wide and 18-feet long.
    1. 4,800 lbs
    2. 18,000 lbs
    3. 36,000 lbs
    4. 54,000 lbs
    5. 84,000 lbs

End of Objective Test

CHAPTER 4

WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

by

Sam Kalichman

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OBJECTIVES

Chapter 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

Following completion of Chapter 7, you should be able to:

1. Identify types of contaminants that could get into water distribution systems,
2. Identify and correct sources of contaminants in distribution systems, and
3. Identify and correct causes of water quality degradation in distribution systems.

GLOSSARY

Chapter 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

AEROBIC (air-O-bick) AEROBIC

A condition in which "free" (atmospheric) or dissolved oxygen is present in the water.

AESTHETIC (es-THET-ick) AESTHETIC

Attractive or appealing.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" (atmospheric) or dissolved oxygen is *NOT* present in water.

BACK PRESSURE BACK PRESSURE

A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

BACKFLOW BACKFLOW

A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than an intended source. Also see BACKSIPHONAGE.

BACKSIPHONAGE BACKSIPHONAGE

A form of backflow caused by a negative or below atmospheric pressure within a water system. Also see BACKFLOW.

CARCINOGEN (car-SIN-o-jen) CARCINOGEN

Any substance which tends to produce a cancer in an organism.

COLIFORM (COAL-i-form) COLIFORM

A group of bacteria which are found in the intestines of warm blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.

CONTAMINATION CONTAMINATION

The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use.

CROSS-CONNECTION CROSS-CONNECTION

A connection between a drinking (potable) water system and an unapproved water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross-connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

ELECTROCHEMICAL REACTION ELECTROCHEMICAL REACTION

Chemical changes produced by electricity (electrolysis) or the production of electricity by chemical changes (galvanic action). In corrosion, a chemical reaction is accompanied by the flow of electrons through a metallic path. The electron flow may come from an external source and cause the reaction, such as electrolysis caused by a D.C. (direct current) electric railway or the electron flow may be caused by a chemical reaction as in the galvanic action of a flashlight dry cell.

ENTRAIN ENTRAIN

To trap bubbles in water either mechanically through turbulence or chemically through a reaction.

INTERFACE INTERFACE

The common boundary layer between two substances such as water and a solid (metal); or between two fluids such as water and a gas (air); or between a liquid (water) and another liquid (oil).

MACROSCOPIC ORGANISMS (MACK-row-SKAWP-ick) MACROSCOPIC ORGANISMS

Organisms big enough to be seen by the eye without the aid of a microscope.

NONPOTABLE (non-POE-tuh-bull) NONPOTABLE

Water that may contain objectionable pollution, contamination, minerals, or infective agents and is considered unsafe and/or unpalatable for drinking.

PALATABLE (PAL-a-ta-ble) PALATABLE

Water at a desirable temperature that is free from objectionable tastes, odors, colors, and turbidity. Pleasing to the senses.

POLLUTION POLLUTION

The impairment (reduction) of water quality by agricultural, domestic, or industrial wastes (including thermal and atomic wastes), to a degree that has an adverse effect on any beneficial use of water.

POTABLE WATER (POE-tuh-bull) POTABLE WATER

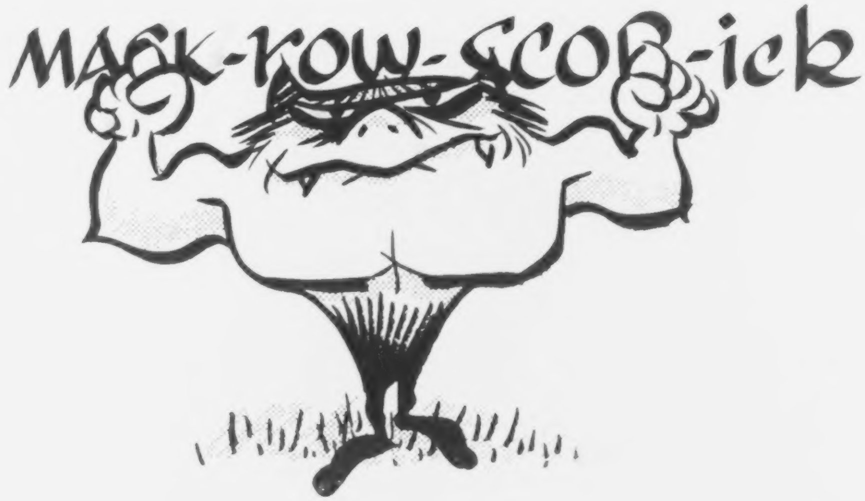
Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

TRIHALOMETHANES (tri-HAL-o-METH-hanes) TRIHALOMETHANES

Derivatives of methane, CH_4, in which three halogen atoms (chlorine or bromine) are substituted for three of the hydrogen atoms. Often formed during chlorination by reactions with natural organic materials in the water. The resulting compounds (THMs) are suspected of causing cancer.

VORTEX VORTEX

A revolving mass of water which forms a whirlpool. This whirlpool is caused by water flowing out of a small opening in the bottom of a basin or reservoir. A funnel-shaped opening is created downward from the water surface.



CHAPTER 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

4.0 IMPORTANCE OF WATER QUALITY

"Water quality" is the general term used to describe the composite chemical, physical and biological characteristics of a water supply. Whether the quality is high or low depends on the suitability of the water for a particular use. A water supply that is satisfactory in quality for one purpose might be entirely unsatisfactory for another. A domestic water supply is considered to be of good quality when it is free of disease-causing organisms and toxic chemicals, attractive in taste and appearance, of such a chemical composition that it may be distributed without undue corrosion or scale-forming effects on the water system and will satisfy, to a maximum degree, the requirements of domestic and industrial consumers.

The quality of water received in the distribution system depends on the quality of the sources used and the type of treatment provided. The first order of quality control calls for prevention of contamination and pollution of the sources. If quality control at the source is not practiced, any breakdown in the treatment provided may result in delivery of questionable quality water (or even dangerous water) to the distribution system. The primary responsibility of the treatment plant is to produce a safe and *PALATABLE*[1] water; however, it should also condition the water to minimize its deterioration within the distribution system.

The importance of providing a water of acceptable quality is obvious. Service of a poor quality water could result in a range of consequences from the water not being acceptable to the consumer because of its appearance or taste, to illness or even death of some susceptible consumers. Each utility and, in turn, each operator working for that utility is responsible for the quality of the water served to its customers.

After a year-long study of water quality in distribution systems, Dr. John T. O'Connor of the University of Illinois reported:

> "Perhaps the single greatest water quality problem which affects the daily lives of most American water consumers results from the deterioration of water quality within water distribution systems. In almost every circumstance, in the United States, the quality of the treated water put into the water distribution mains from the water purification plant is high. However, once the water has entered the distribution system, some fairly substantial changes can occur which the water purveyor (supplier) cannot readily control."

Water quality would not change in the distribution system if the system was inert to water, completely sealed off from any intrusion, and the water was completely stable and biologically sterile. Unfortunately, this situation does not exist, nor will it ever exist. A rather romanticized, but appropriate, statement was made at a British conference on problems associated with the distribution of drinking waters: "A distribution system is not just pipes and valves, but is like a living person — a dynamic, sensitive, individual that must be handled with great care."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 174.

4.0A Water quality is the general term used to describe which characteristics of a water?

4.0B A domestic water supply is considered to be of good quality when it meets what guidelines or criteria?

4.0C What are the consequences of delivering a poor quality water to the consumer?

4.1 WATER QUALITY STANDARDS

The water works industry is in the business of supplying one product — potable water. As in any industry, quality control of this product is necessary. To provide the needed quality control and assure the acceptability of the product, water quality standards have been prepared and used. Some standards have been set by law and must be complied with, while others are merely guidelines. Water quality standards have changed considerably over the years. Increased knowledge of the substances in our water supplies and their effects has led to substantial revisions in both the types and the concentrations of substances allowable in water supplies.

---

[1] *Palatable (PAL-uh-tuh-bull). Water at a desirable temperature that is free from objectionable tastes, odors, colors and turbidity and is pleasing to the senses.*

Standards cannot possibly cover all potential chemicals. They can only include those constituents which are most likely to occur and which could be a significant problem. Existing water quality standards generally relate either to health or to aesthetics (general attractiveness or appeal). Mandatory limits have been set for substances which may result in a risk to the health of humans when present in concentrations above that limit and when continuously used for drinking or cooking purposes. Examples of contaminants in this category are arsenic, barium, chromium, lead and mercury. Substances in the "aesthetics" category are those which may be objectionable to a large number of people, but are not generally hazardous to health. They include color, taste, odor, turbidity, iron and manganese.

The United States National Interim *PRIMARY*[2] Drinking Water Regulations set maximum contaminant levels (MCLs) for 10 inorganic constituents, seven organic constituents, turbidity, coliform organisms, corrosivity and radionuclides. National *SECONDARY*[2] Drinking Water Regulations which are intended as guidelines for the States have also been set. They include seven inorganic constituents, one organic constituent, odor, color, and pH. These regulations are summarized on the poster inside the back cover of this manual.

A more detailed discussion on water quality standards was given in this manual in Chapter 2, "Water Sources and Treatment," in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE*. For additional information see *WATER TREATMENT PLANT OPERATION*, Volume II, Chapter 22, "Water Quality Regulations."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 174.

4.1A Why have water quality standards been prepared and used by the water works industry?

4.1B Drinking water quality standards can generally be categorized as being related either to ___ or to ___.

4.1C MCL stands for what three words?

4.2 TYPES OF CONTAMINANTS

Contaminants found in water served from a distribution system may be chemical, physical or biological in nature. They include, but are not restricted to, those substances already mentioned for which standards have been set.

Chemical contaminants are organic and inorganic substances which may be found as dissolved gases, in aqueous (liquid) solution or in solid form in the water supply. These chemical substances range from simple dissolved gases to inorganic substances and to complex organic compounds. Inorganic substances that can be found in water include dissolved or suspended lead, mercury, fluoride, nitrate and arsenic. Organics are chemical substances which are based on the element carbon. They may be natural substances of animal or vegetable origin such as the humic materials which originate from biological decomposition of plant life and animal remains. They can also be man-made synthetic compounds such as pesticides, herbicides and *TRIHALOMETHANES*.[3]

The physical qualities of water are the ones that are recognized by the consumer and by which consumers judge the water being served to them. These include color, turbidity, taste, odor, and temperature. Other physical items of occasional concern include milky water due to air and *MACROSCOPIC ORGANISMS*[4] such as worms or bugs in the water.

Biological contaminants include the pathogenic (disease-causing) organisms such as bacteria, viruses and intestinal parasites, and the non-pathogenic organisms such as iron bacteria, algal growths, slime growths, insects and insect larvae, nematodes (roundworms), mollusks such as snails and clams, crustacea such as water fleas and cyclops, and small animals and birds. Table 4.1 is a list of pathogenic organisms which can cause disease outbreaks when they contaminate water systems.

4.3 SOURCES OF CONTAMINANTS

Water served from the distribution system may have been of poor quality before it reached the system, or it may degrade in the distribution system itself. Operators must realize that the quality of the water coming out of the consumer's tap can also be affected by what happens to the water as it travels through the customer's own system.

Contamination of water can occur at the source of supply; at the treatment plant; in distribution system storage facilities; or even in water mains. Factors that may cause water quality degradation include cross-connections, corrosion, biological growth and activity, high temperatures, unusual flows, time in system, dead ends, age of facilities, and operational procedures.

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[2] *Primary standards deal with potentially harmful (toxic or disease) constituents; secondary standards deal with aesthetic constituents. Turbidity is an aesthetic concern; however, turbidity interferes with disinfection which is used to kill disease-causing organisms.*

[3] *Trihalomethanes (tri-HAL-o-METH-hanes). Derivatives of methane, CH_4, in which three halogen atoms (chlorine or bromine) are substituted for three of the hydrogen atoms. Often formed during chlorination by reactions with natural organic materials in the water. The resulting compounds (THMs) are suspected of causing cancer.*

[4] *Macroscopic Organisms (MAC-row-SKAWP-ick). Organisms big enough to be seen by the eye without the aid of a microscope.*

TABLE 4.1 PATHOGENIC ORGANISMS (DISEASES TRANSMITTED BY WATER)

Bacteria
- Salmonella (salmonellosis)
- Shigella (bacillary dysentery)
- Bacillus typhosus (typhoid fever)
- Salmonella paratyphi (paratyphoid)
- Vibrio cholerae (cholera)

Viruses
- Enterovirus
  - Poliovirus
  - Coxsackie Virus
  - Echo Virus
- Andenovirus
- Reovirus
- Infectious Hepatitis

Intestinal Parasites
- Entamoeba histolytica (amoebic dysentery)
- Giardia lamblia (giardiasis)
- Ascaris lumbricoides (giant roundworm)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 174.

4.2A What are trihalomethanes (THMs)?

4.2B What physical qualities of water are important to consumers?

4.3A Where might contamination of water occur?

4.3B How can water be degraded in the distribution system?

4.4 WATER SUPPLIED TO DISTRIBUTION SYSTEMS

4.40 Source of Supply

The quality of water entering the distribution system may have been adversely affected at the source or at the treatment plant. "Natural" source waters are never completely pure. During their precipitation (falling as rain or snow) and their passage over or through the ground, they can acquire a wide variety of dissolved or suspended impurities. Some of these impurities come from decaying vegetation or minerals in the soils. Other impurities result from the activities of man; waste discharges are of particular concern. Surface waters are exposed and especially susceptible to contamination. They can be degraded by domestic, industrial and agricultural waste discharges and spills; humic materials such as decaying vegetation; refuse disposal; recreation; construction; animal activities; uncontrolled growths of algae and weeds; and radioactive fallout.

Groundwaters are less susceptible to contamination, but once they are contaminated, it normally takes a considerable time before they recover. This is due to the slow movement of the water in the ground. The groundwaters themselves may become contaminated or poorly constructed wells may contribute degraded water to the system. This degraded water may come from surface water moving above the groundwater table or from contaminants at or near the ground surface. Contamination may also result from leaching from nearby domestic, industrial or agricultural wastewater operations or disposals; spills; humic material; flood waters; or passage through natural mineralized formations.

CARCINOGEN
DISTRIBUTION SYSTEM

4.41 Treatment Plant

If a water treatment plant is not being operated effectively and reliably, the substances that are to be removed or altered can pass into the distribution system substantially unchanged. For example, a chlorinator breakdown could result in pathogenic organisms entering the distribution system. Chemicals used at water treatment facilities can also cause quality problems as when chlorination of water containing organic materials results in the formation of trihalomethanes (which are suspected *CARCINOGENS*[5]). Improper chlorination can cause objectionable tastes and odors; overdosing of alum during coagulation treatment can result in turbidity and deposits; and excessive use of manganese compounds for taste and odor control can result in a colored water.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 175.

4.4A Why are "natural" source waters never completely pure?

4.4B How can surface waters become contaminated or degraded?

4.4C How can groundwaters become contaminated or degraded?

4.4D What problems can be created by improper chlorination in water treatment plants?

4.5 DISTRIBUTION SYSTEMS

Many conditions exist which could result in degradation of water quality in the distribution system. The system operator must be aware of them and take corrective or protective measures where possible. This section discusses the general causes of quality degradation in distribution systems, particularly in water mains and storage facilities.

---

[5] *Carcinogen (car-SIN-o-jen). Any substance which tends to produce cancer in an organism.*

4.50 Causes of Quality Degradation in Distribution Systems

4.500 Cross-Connections

A cross-connection can be defined as an unprotected connection between any part of a water system used or intended to be used to supply water for drinking purposes and any source or system containing water or a substance that is not or cannot be approved as safe, wholesome and potable for human consumption. Contamination resulting from *BACKFLOW*[6] of unacceptable substances through cross-connections to distribution systems has consistently caused more water-borne disease outbreaks in the United States than any other reported factor. Backflow can occur through a cross-connection either by "backsiphonage" or "back pressure." Backsiphonage is a form of backflow caused by negative (below atmospheric) pressure in the water supply piping. Backsiphonage can develop from such causes as main breaks, inadequate source of supply capacity, undersized mains, unusual water demands, planned shutdowns for maintenance or repair, or the use of on-line booster pumps. Backflow caused by "back pressure" can occur when the user's water system is at a higher pressure than the public water system. Examples of sources of back pressure are services to premises where wastewater or toxic chemicals are handled under pressure, or where there are unapproved auxiliary supplies such as a private well.

4.501 Corrosion

Corrosion is the gradual deterioration or destruction of a substance or material by chemical action proceeding inward from the surface. Corrosion is frequently induced by *ELECTROCHEMICAL REACTIONS.*[7] Corrosion is of significant health and economic, as well as aesthetic, significance. Elevated levels of toxic or suspected toxic substances such as lead, cadmium, copper, zinc, asbestos, and certain organic compounds have been found in water being served from distribution systems as the result of corrosive action of water on the distribution system materials. Increased incidences of cardiovascular (heart) disease have been associated with consumption of a soft, corrosive water.

Perhaps the greatest water quality nuisance is the corrosion and precipitation of iron. "Red" water is the most common consumer complaint. The exact chemistry of how iron goes into solution and subsequently precipitates to yield rusty or "red" water is not fully understood. However, it appears that a number of different microorganisms are involved. Bacteria are rarely absent where iron is found in abundance in treated waters. The iron bacteria, *CRENOTHRIX,* are of special concern. These bacteria precipitate iron which forms the deposits in pipes, reduces carrying capacity, and produces color in water. The dead organisms also impart a disagreeable taste to the water. Improper potassium permanganate feed may also cause red colored water.

SUGGESTION:
'RED' WATER IS
IDEAL FOR
COOKING BEETS!

Of the materials used for construction in water systems, metals are the most susceptible to corrosion; however, asbestos-cement pipe is also susceptible, and plastic (such as PVC or polyvinylchloride) pipe is the least susceptible to corrosion. To prevent corrosion of cast iron (ductile iron) or steel pipes and to aid in the curing of cement-lined pipes, the inner side of such pipes may be lined with asphalt or coal tar materials. The types and durability of coatings for corrosion control are of special importance; however, some coatings can impart taste and odors to the water. Because of its importance and complexity, corrosion is discussed in detail in Chapter 8, "Corrosion Control," *WATER TREATMENT PLANT OPERATION,* Volume I.

4.502 Biological Growth and Activity

Regardless of the efficiency of the treatment process, some microorganisms will enter the water and possibly interact with the distribution system. Geldrich and others with the EPA have reported that in waters with turbidity as low as 3.8 units, coliform bacteria have been observed to consistently survive 0.1 to 0.5 mg/*L* free chlorine residual after 30 minutes contact time. Some non-coliform organisms may be even more resistant. The survival and possible regrowth of these organisms may be affected by such factors as the amount of exposure to residual concentrations of chlorine, the amount of bacterial nutrients in the deposits, and water temperatures. The term "aftergrowth" has been used to describe the development of coliform organisms in distribution systems even though water delivered to the system meets bacterial standards and where other causes of contamination of the water appear unlikely.

Pockets of sediment deposited in the distribution system or pipe encrusted with chemical deposits (Figure 4.1) may form protected habitat for these organisms. Such deposits often consist of silt, coagulants, precipitated chemicals or products of corrosion. Some deposits have been found to contain bacterial populations of more than 100,000 organisms per gram.

Slimes are organic substances of a viscous nature formed from microbiological growth. Tastes and odors can be produced by slime growths of organisms that thrive on ammonia, iron, sulfide, and methane. The development of the iron bacteria *CRENOTHRIX* also results in slime growths.

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[6] *Backflow. A reverse flow condition created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than an intended source. Also see BACKSIPHONAGE.*

[7] *Electrochemical Reaction. Chemical changes produced by electricity (electrolysis) or the production of electricity by chemical changes (galvanic action). In corrosion, a chemical reaction is accompanied by the flow of electrons through a metallic path. The electron flow may come from an external source and cause the reaction, such as electrolysis caused by a D.C. (direct current) electric railway or the electron flow may be caused by a chemical reaction as in the galvanic action of a flashlight dry cell.*

Increasing levels of microbial activity can ultimately result in increased consumer complaints as well as accelerated corrosion and reduced flow from greater turbulence along the pipe walls. Taste and odor problems may result from the death and decay of organisms after heavy chlorination.

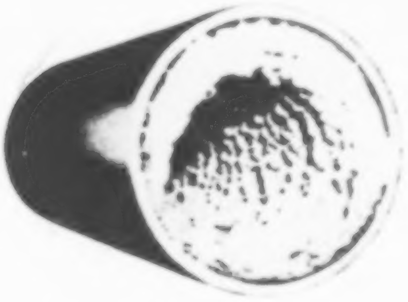


Fig. 4.1 Pipe encrusted with chemical deposits

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 175.

4.5A What is the most frequently reported cause of waterborne disease outbreaks in the United States?

4.5B What are the two causes of backflow through a cross-connection?

4.5C How can corrosion cause health problems?

4.5D Slime growths can cause what problems in distribution systems?

4.503 Temperature

Water temperature has three major impacts on system water quality: (1) higher temperatures tend to speed the rate of chemical reactions and increase biological growth rates; (2) biological decomposition may be intensified by summer temperatures; and (3) chlorine demand may be considerably greater so residuals won't carry as far in the distribution system in the summer.

4.504 Flow

Large variations in flow through a system may adversely affect water quality in three ways. First, changes in water velocity and flow reversals can result in sediments being stirred up and carried along until they reach the consumer. Second, low circulation and stagnant water can result in the growth of organisms, formation of sediments and corrosion products, depletion of oxygen and increased tastes and odors. And third, turbulence can *ENTRAIN*[8] air into the supply causing "milky" water which is objectionable to consumers.

4.505 Time in System

The "age" of water at a particular point in the distribution system can influence water quality. "Age" is defined as the total time from the entrance of the water into the system until it reaches a specific point of measurement. Water delivered to consumers close to the source might be only minutes old, while that received at remote parts of the system might have been in the system for several days or more depending on storage and demands. The longer the water is in the system, the more time is available for chemical and biological changes to take place.

4.506 Age of Facilities

As water mains and reservoirs become older, they require more and more maintenance. Gradual deterioration in protection against corrosion may lead to water quality problems. Ruptures and leaks in piping become more frequent. In older systems, it is not uncommon to find that the pipes and tanks were of poor construction when installed and perhaps had little or no protective coating even when new.

4.507 Operation

Careless or poor operating procedures can also result in water quality degradation. These include inadequate cross-connection control, poorly performed water quality monitoring and flushing programs, tolerance of low or negative pressures in the distribution system, insufficient surveillance to determine whether the protective features for storage facilities and mains are still adequate, inadequate disinfection after repair or installation of new facilities, and disregard for the hazards of installing facilities such as sewers in close proximity to water lines and reservoirs. The lack of trained, qualified, adequately paid operators contributes to the problem.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 175.

4.5E High water temperatures can cause what problems to system water quality?

4.5F What problems can be caused by low flows?

4.5G How is water affected by the length of time it remains in a distribution system?

4.5H What problems can develop as transmission and storage facilities grow older?

4.5I How do water supply system operators contribute to the degradation of water quality in distribution systems?

4.51 Quality Degradation in Water Mains

In addition to the above considerations, quality deterioration can occur in mains because of pipe characteristics, material, construction and location. The causes of such deterioration are discussed in the following paragraphs.

---

[8] *Entrain. To trap bubbles in water either mechanically through turbulence or chemically through a reaction.*

4.510 Large Interior Surface Areas

Substances can be deposited, biological growths attached, and corrosion reactions can take place on the inside surfaces of pipe walls. The large interior surface area available provides considerable space for these activities to take place. For example, 1 mile (1600 km) of 6-inch (150 mm) diameter pipe has 8300 sq ft (770 sq m) of inside pipe surface. Reduced flows permit greater chemical and biological activity to take place at the *INTERFACE*[9] where the pipe and water meet. This relatively quiet zone is capable of harboring considerable chemical or biological activity. Therefore, the quality conditions next to the pipe wall may be quite different than those in the main stream flow. In smaller mains, the ratio of surface area to volume of water is much greater, making the quality problems in these mains much more likely to be serious if chemical or biological activity occurs.

4.511 Dead Ends

The lack of circulation in a dead end creates nearly ideal conditions for degrading of water quality. The velocity is very low if not zero; the time of contact of water with the pipe and any deposits, encrustations, or slimes is long; there may be an accumulation of organic matter containing nutrients; organisms grow and use the available dissolved oxygen; oxygen may be depleted, thus initiating *ANAEROBIC*[10] conditions which produce carbon dioxide, methane and foul sulfide odors. Carbon dioxide may increase the corrosion potential. Chlorination treatment, if provided, may not even be effective because of increased demand by organics, biological forms, and corrosion products.

4.512 Pipe Material

Pipes generally are made of metal, asbestos-cement, or plastic. In metal and asbestos-cement pipe, corrosion can cause the release of substances from the piping materials into the water. With coal tar-lined or plastic pipe, however, the physical characteristics of the water are of minor importance; the concern is the possibility of leaching of material from the pipe or the lining by the water. To prevent corrosion, the insides of cement or metal pipes may be lined with asphalt or coal tar coatings. The potential for corrosion then relates to the integrity (durability) of these coatings.

Of special concern are systems which still have considerable unlined pipe in the ground and therefore are more susceptible to corrosion problems. When pipes of dissimilar metals are connected, there may be increased corrosion near the connection. Asbestos-cement pipe will deteriorate if aggressive water conditions exist, thus releasing increasing amounts of asbestos fibers. Corrosion has been discussed here to a limited degree and is discussed in more detail in Chapter 8, "Corrosion Control," in *WATER TREATMENT PLANT OPERATION*, Volume I, in this series of manuals.

4.513 Pipe Construction and Repair

There is ample opportunity for entry of contaminants during construction of new mains and repair of old mains. To assure the safety of the delivered water, proper protective, cleaning and disinfection practices must be followed. When lines are being repaired, keep the hole dewatered to prevent possible contamination of the water line. After the line has been repaired, thoroughly flush the line downstream from the repair to remove any dirt and mud that may have entered the line. Flushing is important not only for health reasons, but to avoid consumer complaints. After flushing, the line should be disinfected before being returned to service. See Chapter 8, "Distribution System Operation and Maintenance," and Chapter 9, "Disinfection," for procedures on how to flush and disinfect water mains.

4.514 Proximity to Hazardous Facilities

When physical conditions or soil conditions prevent minimum separation distances from being met, water mains may be located adjacent to sewer lines, fuel lines, individual septic tanks and disposal systems, or tanks containing dangerous materials. If leakage from such hazardous facilities saturates the soil around the mains, the mains could become contaminated. When they are out of service for any reason and are not under pressure (or are under negative pressure) contamination may seep into the lines through cracked or inadequately sealed joints.

4.515 Appurtenances

Distribution system water quality can be adversely affected by improperly constructed or poorly located blow-offs or vacuum/air-relief valves. They may be located where they could become flooded and permit the entrance of contaminated water when they are open. A lack of blow-offs would make it difficult or impossible to correct a poor quality condition, or at least to give temporary relief. Air valves (or some form of manual air bleed valve) are important to relieve entrapped air and to help prevent milky water and surge problems when lines are being filled.

4.516 Operation

Hydrant testing and flushing programs can result in dirty water reaching consumers — and bring numerous complaints to the water utility. The dirty water results from high water velocities suspending material that has settled out and accumulated on the bottoms of water mains. For additional information on how to test hydrants, flush mains and respond to dirty water complaints, see Chapter 8, "Distribution System Operation and Maintenance."

---

[9] *Interface. The common boundary layer between two substances such as water and a solid (metal) or between two fluids such as water and a gas (air); or between a liquid (water) and another liquid (oil).*

[10] *Anaerobic (AN-air-O-bick). A condition in which "free" (atmospheric) or dissolved oxygen is NOT present in water.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 175.

4.5J What problems can develop at the interface where the distribution pipe and water meet?

4.5K Why may a chlorine residual not be effective at the dead end of a water main?

4.5L What is the major water quality concern regarding coal tar-lined pipe or plastic pipe?

4.5M How can water be protected from contaminants that enter the system during construction of new mains and repair of old mains?

4.5N What is the purpose of air valves (or some form of air-bleed valve)?

4.5O What problem might result from hydrant testing and flushing programs?

4.52 Quality Degradation in Storage Facilities

Tanks and reservoirs provide significant opportunity for pollution or contamination of the water they contain. Water in these facilities is not normally under pressure, the facility is never completely tight (except for pressure tanks), and there may be exposure to many sources of pollution. For a summary of problems, causes and solutions, see Table 2.1, "Troubleshooting Water Quality Problems in Storage Tanks and Distribution systems," page 34.

4.520 Uncovered Reservoirs

The use of distribution reservoirs which do not have covers is not encouraged and is often prohibited. Open reservoirs are the most vulnerable part of a water system (Figure 4.2). They are subject to contamination from vandalism; wind-blown and atmospheric contaminants; birds, animals and rodents; and illegal bathing and fishing. Drownings have even occurred. Materials have been thrown into them either maliciously, carelessly, or for sabotage. An outbreak of salmonellosis in Alaska was attributed to sea gull contamination of a reservoir on a hill not far from where gulls had access to bay waters contaminated by raw domestic wastewater. Algae develop more readily in open reservoirs and may produce taste and odor problems. The larvae of the chironomid gnat are small worms and infestation of these worms in some distribution systems has led to severe consumer complaints. In most instances, the infestation started after deposition of gnat eggs in open reservoirs.

4.521 Inadequate Covers (Figure 4.3 and 4.4)

If covers are not properly maintained, animal, bird and windblown contamination can enter through exposed openings in roofs or torn screening. A poorly constructed reservoir roof can often be worse than no roof at all in contributing contamination materials since bird droppings, dust, and other materials which have accumulated on a roof over a long seasonal dry period might be washed into the reservoir in a short period of time. If the vent areas on the roof are not protected, rain and wind-blown roof drainage debris may enter through these areas into the reservoir.

4.522 Below-Ground Construction (Figure 4.5)

Reservoirs which have part or all of their side walls below ground (cut and fill types) are subject to contamination from any materials leaching through the soils and getting into the reservoir vicinity if there is a failure (crack) in the side wall. Nearby septic systems or wastewater facilities are of special concern. Below-ground reservoirs are also more susceptible to flooding by surface storm waters, to wind-blown contamination, and are easier to vandalize as both roof and side wall vents are nearer to ground level and thus more accessible.

4.523 Other Sources

Improperly screened overflows may permit the entrance of small animals. Any cross-connection between a drain or overflow and a sewer line is considered to be a serious hazard because it may result in a backflow of wastewater into the reservoir. Reservoirs which are not heavily used can be a source of taste, odor and contamination problems.

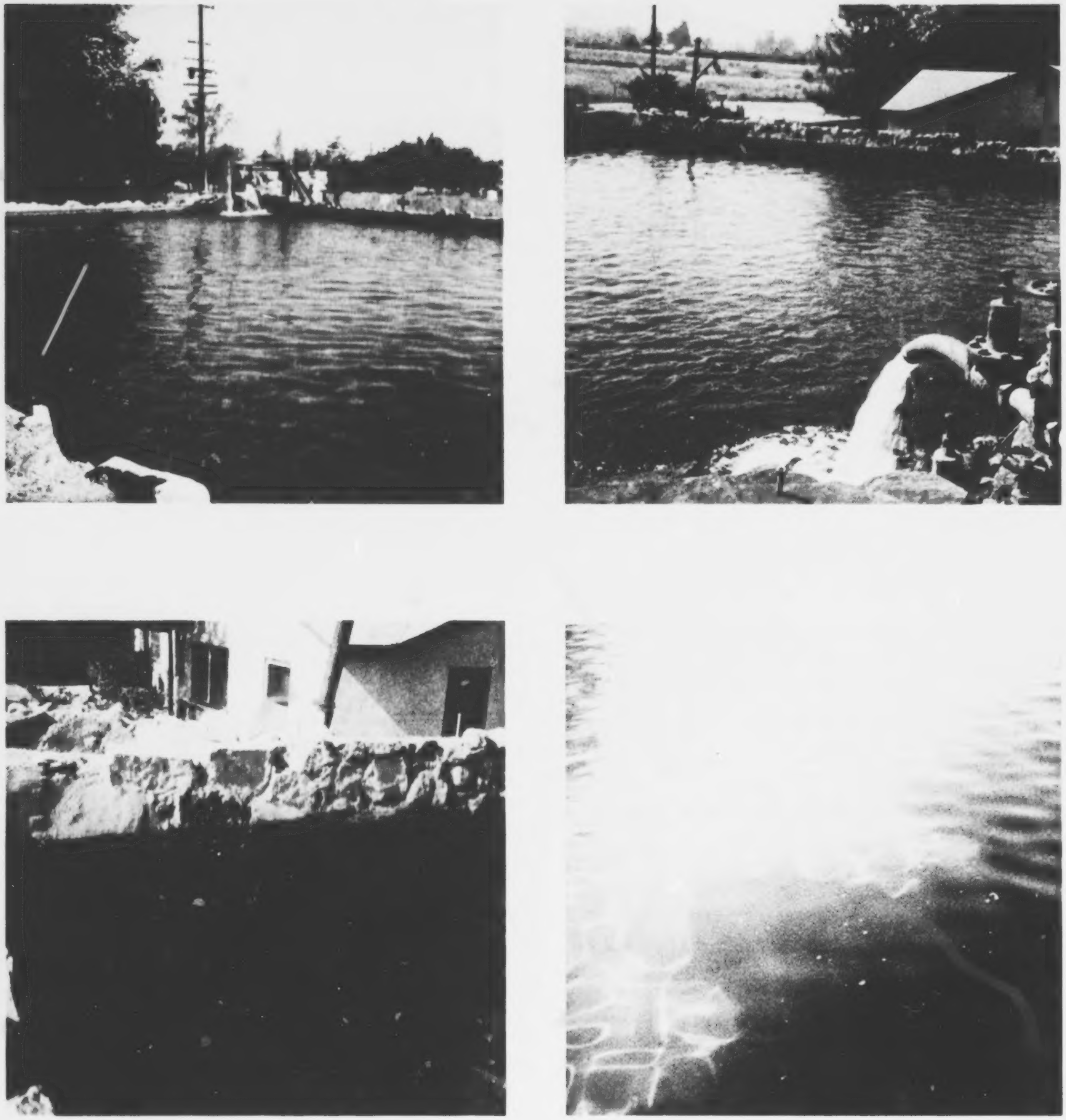
4.524 Operation

Inadequate disinfection of reservoirs (or no disinfection at all) after construction or repairs may well result in degradation of water quality. If the water level in a reservoir is permitted to get too low, a *VORTEX*[11] will be formed in the water being discharged. Air may be entrained or materials that have settled in the bottom of the reservoir may be stirred up and get into the mains and the customers' service lines.

Reservoirs should be inspected at least twice a month. Remove any surface debris. In many cases the water quality of a storage facility is related to water clarity and surface debris.

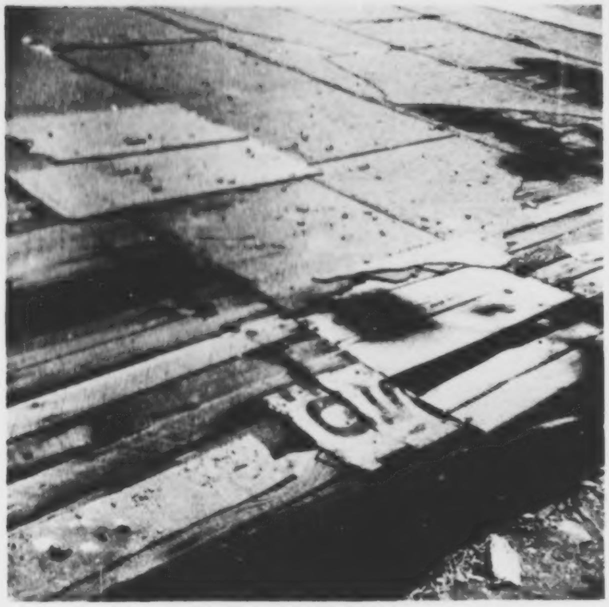
---

[11] *Vortex. A revolving mass of water which forms a whirlpool. This whirlpool is caused by water flowing out of a small opening in the bottom of a basin or reservoir. A funnel-shaped opening is created downward from the water surface.*



Note floating material having appearance of grease balls in lower pictures.

Fig. 4.2 Open reservoir



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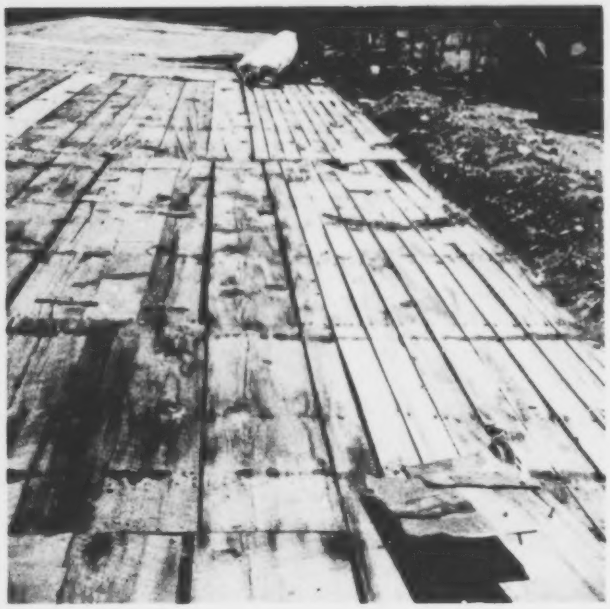

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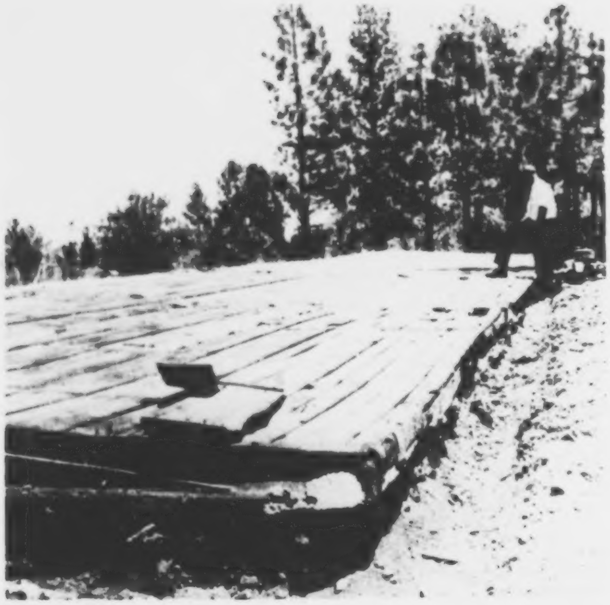


3

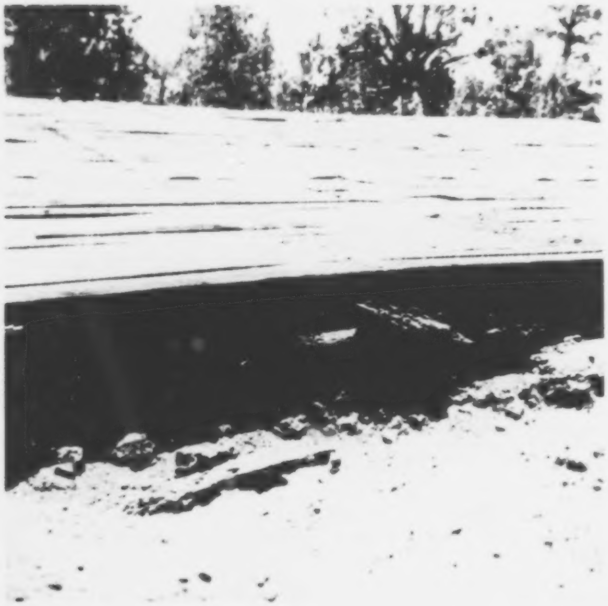
Note openings in reservoir roof, lack of roofing paper, and general unsatisfactory conditions.

Fig. 4.3 Reservoir roof

4

5

Note rodent droppings next to pencil on concrete ledge inside reservoir.



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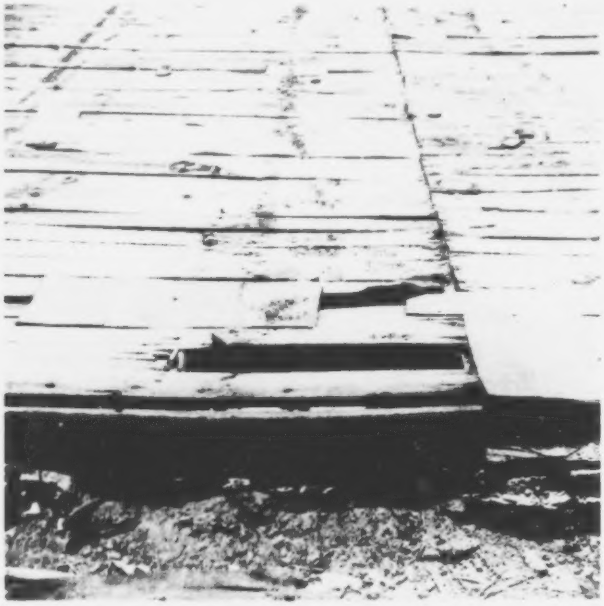

7

Note deteriorated and rotting sills and openings along sides into reservoir.

Fig. 4.4 Defective reservoir roof

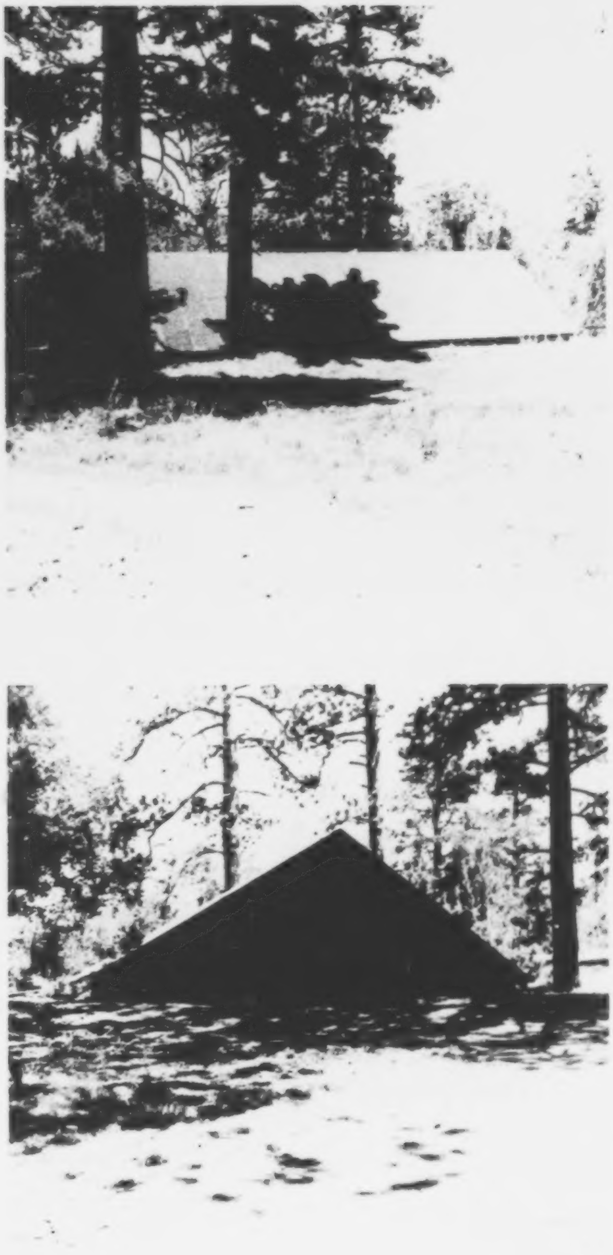

Fig. 4.5 Reservoir with most of sidewall below ground

4.53 Water Quality Monitoring

Water quality monitoring of distribution systems is important to identify when and where water quality changes occur in the system. Routine monitoring consists of collecting samples at remote locations in the system and testing for chlorine residual and coliforms. The minimum number of samples per month is based on the population served. When problems or complaints develop, a more detailed monitoring program is required to identify the cause and source of the problem. See Chapter 5, Distribution System Operation and Maintenance, Section 5.2, "Water Quality Monitoring," for more details.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 175.

4.5P How can open reservoirs become contaminated?

4.5Q Why can a poorly constructed reservoir roof be worse than no roof at all in terms of contamination?

4.5R What are some of the problems associated with below-ground reservoirs?

4.5S Why should the water level in storage facilities not be allowed to get too low?

4.6 TROUBLESHOOTING

This chapter has described the importance of water quality considerations in distribution systems. Types and sources of contaminants and causes of water quality degradation in water mains and storage facilities have been discussed. These water quality problems should not develop in properly designed, constructed, operated and maintained water distribution systems.

Chapter 5, "Distribution System Operation and Maintenance," contains information on how to properly operate and maintain distribution systems. Also, procedures are outlined there on how to identify and locate the sources of problems causing water quality degradation and potential solutions to the problems.

4.7 ARITHMETIC ASSIGNMENT

Turn to the Appendix at the back of this manual and read all of Section A.7, "Velocity and Flow Rate." Work all of the problems on your pocket calendar. You should be able to get the same answers.

4.8 ADDITIONAL READING

NEW YORK MANUAL, Chapter 17, "Protection of Treated Water."

DISCUSSION AND REVIEW QUESTIONS

Chapter 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

Write your answers to these questions in your notebook before continuing with the Objective Test on page 176.

1. What are the major sources of contaminants in a water distribution system?
2. How may water quality be degraded in water mains?
3. Under what conditions might water storage facilities contribute to water quality degradation?
4. What water quality criteria must a good quality domestic water supply meet?
5. How can water treatment plants contribute to water quality problems in a water distribution system?
6. What operational deficiencies can result in water quality degradation?
7. How can water be degraded in dead ends?
8. What are some typical types of hazardous facilities that should not be located near water mains?

SUGGESTED ANSWERS

Chapter 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

Answers to questions on page 163.

4.0A Water quality is the general term used to describe the composite chemical, physical and biological characteristics of a water.

4.0B A domestic water supply is considered to be of good quality when it is free of disease-causing organisms and toxic chemicals, attractive in taste and appearance, of such a chemical composition that it may be distributed without undue corrosive or scale-forming effects on the water system, and will satisfy, to a maximum degree, the requirements of domestic and industrial consumers.

4.0C The consequences of delivering a poor quality water to the consumer range from the water not being acceptable to the consumer because of its appearance or taste, to illness or even death of some susceptible consumers.

Answers to questions on page 164.

4.1A Water quality standards have been prepared and used by the water works industry to provide the needed quality control and to insure the acceptability of the product water.

4.1B Drinking water quality standards can generally be categorized as being related either to *HEALTH* or *AESTHETICS.*

4.1C MCL stands for **M**aximum **C**ontaminant **L**evel.

Answers to questions on page 165.

4.2A Trihalomethanes (THMs) are derivatives of methane, CH_4, in which three halogen atoms (chlorine, bromine) are substituted for three of the hydrogen atoms. These may be formed during chlorination by reactions with organic materials. The resultant compounds are suspected of being carcinogens.

4.2B Physical qualities of water important to consumers include color, turbidity, taste, odor and temperature. Other items of physical concern include milky water due to air and macroscopic organisms such as worms or bugs in the water.

4.3A Contaminants can enter the water supplied to the distribution system either through the source of the water supply or the water treatment plant.

4.3B Water can be degraded in the distribution system by cross-connections, corrosion, biological growth and activity, high temperatures, unusual flows, time in system, age of facilities and operational procedures.

Answers to questions on page 165.

4.4A "Natural" source waters are never completely pure because during their precipitation (falling as rain or snow) and their passage over or through the ground, they acquire a wide variety of dissolved or suspended impurities.

4.4B Surface waters can become contaminated or degraded from domestic, industrial or agricultural waste discharges and spills; humic materials such as decaying vegetation; refuse disposal; recreation; construction; animal activities; uncontrolled growths of algae and weeds; and radioactive fallout.

4.4C Groundwaters may become contaminated or degraded by leaching from nearby wastewater, industrial or agricultural operations or disposals; spills; humic materials; flood waters; or passage through natural mineralized formations.

4.4D Improper chlorination in water treatment plants can cause tastes and odors in waters delivered to consumers.

Answers to questions on page 167.

4.5A Cross-connections are the most frequently reported cause of water-borne disease outbreaks in the United States.

4.5B Backflow through a cross-connection can occur either by "backsiphonage" or "back pressure."

4.5C Corrosion can cause health problems by increasing the levels of toxic or suspected toxic substances in water such as lead, cadmium, copper, zinc, asbestos, and certain organic compounds. Increased incidences of cardiovascular (heart) disease have been associated with consumption of soft, corrosive water.

4.5D Slime growths can cause taste and odor problems in water distribution systems. Microbial activities can result in accelerated corrosion and reduced flow due to turbulence.

Answers to questions on page 167.

4.5E High water temperatures tend to speed the rate of chemical reactions and biological growth rates. Biological decomposition may also be intensified. Chlorine demand may be considerably greater so residuals may not carry as far into the distribution system.

4.5F Low flows can contribute to the growth of organisms, formation of sediments and corrosion products, depletion of oxygen and increased tastes and odors.

4.5G The longer water is in the distribution system, the more time is available for chemical and biological changes to take place.

4.5H As facilities grow older, protection against corrosion deteriorates and ruptures and leaks become more frequent.

4.5I The lack of trained, qualified, adequately paid water supply system operators contributes to distribution system problems because of their inability to prevent or solve these problems. Careless operation and poor procedures can also contribute to reduced water quality.

Answers to questions on page 169.

4.5J The interface where the pipe and water meet is a relatively quiet zone capable of harboring considerable chemical or biological activity. This activity could cause water quality degradation.

4.5K A chlorine residual may not be effective at the dead end of a water main because of the increased chlorine demand by organics, biological forms, and corrosion products at that point.

4.5L The major water quality concern in the case of coal tar-lined pipe or plastic pipe is the leaching of material from the pipe or the lining by the water.

4.5M Contaminants that enter the system during construction of new mains and repair of old mains are removed by proper protective, cleaning and disinfection practices.

4.5N Air valves or some form of air-bleed valve are important to relieve entrapped air and to help prevent milky water when lines are being filled.

4.5O Hydrant testing and flushing programs can result in dirty water reaching consumers with resulting numerous complaints.

Answers to questions on page 173.

4.5P Open reservoirs are subject to contamination from vandalism; wind-blown and atmospheric contaminants; birds, animals and rodents; and illegal bathing and fishing. Drowning has occurred; materials have been thrown into reservoirs; birds can carry salmonellosis into open reservoirs; and algae can cause taste and odor problems.

4.5Q A poorly constructed reservoir roof can be worse than no roof at all in contributing contamination materials since bird droppings, dust and other materials which have accumulated on the roof over a long seasonal dry period might be washed into the reservoir in a short period.

4.5R Below-ground reservoirs may be subject to contamination from materials leaching through soils and then through cracks or openings in the side wall. Below-ground reservoirs are also more susceptible to flooding by surface storm waters, to wind-blown contamination, and are easier to vandalize as both roof and side wall vents are nearer to ground level and thus more accessible.

4.5S The water level in storage facilities should not be allowed to get too low because a vortex could be formed in the water being discharged. Air may be entrained or materials that have settled in the bottom of the reservoir may be stirred up and get into the mains and then into the customers' service lines.

OBJECTIVE TEST

Chapter 4. WATER QUALITY CONSIDERATIONS IN DISTRIBUTION SYSTEMS

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True — False

1. A water satisfactory in quality for one purpose or use will be entirely satisfactory for another purpose.
    1. True
    2. False
2. The first order of water quality control calls for prevention of contamination and pollution at the water treatment plant.
    1. True
    2. False
3. Water served to consumers from the distribution system may have been degraded before it reached the distribution system.
    1. True
    2. False
4. Water quality standards for drinking water cover all potentially harmful chemicals.
    1. True
    2. False
5. The water quality conditions next to a pipe wall are the same as those in the main stream flow.
    1. True
    2. False
6. Water served to consumers may have been degraded in the distribution system.
    1. True
    2. False
7. Coliform bacteria are considered pathogenic organisms.
    1. True
    2. False
8. Open reservoirs are the most vulnerable part of a water system for contamination.
    1. True
    2. False
9. Groundwaters quickly recover from contamination.
    1. True
    2. False
10. Chemicals used at water treatment facilities can cause water quality problems for consumers.
    1. True
    2. False

Multiple Choice

11. Water quality criteria important for a good municipal water supply include
    1. Absence of toxic chemicals.
    2. Attractive taste.
    3. Freedom from disease-causing organisms.
    4. Milky appearance.
    5. Warm temperature.
12. Chemicals found in water supplies that could be harmful to a person's health when present in excess of standards in drinking water include
    1. Arsenic.
    2. Iron.
    3. Lead.
    4. Manganese.
    5. Mercury.
13. Pathogenic organisms which can cause disease outbreaks in water systems include
    1. Coliforms.
    2. *CRENOTHRIX.*
    3. *GIARDIA.*
    4. Infectious hepatitis virus.
    5. Salmonella.
14. Which chemicals used at a water treatment plant could cause water quality problems in the water distribution system?
    1. Activated carbon.
    2. Alum.
    3. Chlorine.
    4. Manganese.
    5. Ozone.
15. Surface waters can be degraded by
    1. Algal growths.
    2. Decaying vegetation.
    3. Natural purification.
    4. Recreation activities.
    5. Wildfires on the watershed.
16. Relatively high water temperatures in the distribution system tend to
    1. Increase chlorine demand.
    2. Increase amount of water consumers drink.
    3. Intensify biological decomposition in mains.
    4. Speed biological growth rates.
    5. Speed the rate of chemical reactions.
17. Backsiphonage can develop from such causes as
    1. Check valves.
    2. Elevated tanks.
    3. Main breaks.
    4. On-line booster pumps.
    5. Pressure-reducing valves.

18. Operational deficiencies that can cause water quality degradation include
    1. Effective cross-connection inspection program.
    2. Ignoring installation of sewers close to water mains.
    3. Maintaining a chlorine residual throughout the distribution system.
    4. Regular inspection of storage facilities for protective features.
    5. Tolerance of low pressure in mains.

19. Hazardous facilities that may threaten water quality in distribution mains include
    1. Backwash tanks.
    2. Fuel lines.
    3. Hydropneumatic tanks.
    4. Individual septic tanks and disposal systems.
    5. Sewer lines.

20. Uncovered reservoirs are subject to contamination from
    1. Atmospheric contaminants.
    2. Bathing.
    3. Birds.
    4. Fishing.
    5. Vandalism.

21. Estimate the water velocity in feet per second in an open channel if a float travels 50 feet in 24 seconds.
    1. 0.25 ft/sec
    2. 0.40 ft/sec
    3. 1.0 ft/sec
    4. 2.0 ft/sec
    5. 2.5 ft/sec

22. Estimate the water flow rate in cubic feet per second (CFS) in a canal five feet wide when the water is four feet deep and the water velocity is three feet per second.
    1. 3 CFS
    2. 20 CFS
    3. 36 CFS
    4. 60 CFS
    5. 360 CFS

23. Estimate the water flow rate in a six-inch diameter pipe in gallons per minute (GPM) when the flow velocity is three feet per second.
    1. 265 GPM
    2. 295 GPM
    3. 489 GPM
    4. 38,160 GPM
    5. 70,416 GPM

24. Estimate the flow velocity in feet per second in a 10-inch diameter pipe when the flow rate is two cubic feet per second (CFS).
    1. 1.8 ft/sec
    2. 2.5 ft/sec
    3. 2.7 ft/sec
    4. 3.0 ft/sec
    5. 3.7 ft/sec

End of Objective Test

CHAPTER 5

DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

by

Sam Kalichman

and

Nick Nichols

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OBJECTIVES

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

Following completion of Chapter 8, you should be able to:

1. Develop and conduct a water distribution system surveillance program,
2. Develop and conduct a water quality monitoring program for a water distribution system,
3. Develop and conduct a cross-connection control program,
4. Locate buried pipes and leaks,
5. Repair leaks,
6. Make pipe connections.
7. Flush pipes,
8. Clean pipes,
9. Contract out a pipe lining job,
10. Thaw frozen pipes and hydrants,
11. Test and read meters,
12. Disinfect mains and storage facilities,
13. Develop a recordkeeping system and keep accurate records,
14. Train operators to prepare for and respond to emergencies,
15. Effectively deal with the public,
16. Maintain the landscaped areas around distribution system facilities, and
17. Safely operate and maintain a water distribution system.

GLOSSARY

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

AUDIT, WATER AUDIT, WATER

A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

C FACTOR C FACTOR

A factor or value used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between the pressure gages, and the friction or energy loss of the water between the gages.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.74\ (\text{Diameter, ft})^{2.63}\ (\text{Slope})^{0.54}}$$

CAVITATION (CAV-uh-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises like someone is pounding on the impeller or gate with a hammer.

COUPON COUPON

A steel specimen inserted into water to measure the corrosiveness of water. The rate of corrosion is measured as the loss of weight of the coupon (in milligrams) per surface area (in square decimeters) exposed to the water per day.

10 decimeters = 1 meter = 100 centimeters

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small vertical tube connected to the pipe.

HYDRAULIC GRADIENT HYDRAULIC GRADIENT

The slope of the hydraulic grade line. This is the slope of the water surface in an open channel, the slope of the water surface of the groundwater table, or the slope of the water pressure for pipes under pressure.

PRIME PRIME

The action of filling a pump casing with water to remove air. Most pumps must be primed before startup or they will not pump any water.

SANITARY SURVEY SANITARY SURVEY

A detailed evaluation and/or inspection of a source of water supply and all conveyances, storage, treatment and distribution facilities to insure its protection from all pollution sources.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure [in feet (meters) of water or inches (centimeters) of mercury vacuum] on the suction side of the pump. The pressure can be measured from the centerline of the pump *DOWN TO* (lift) the elevation of the hydraulic grade line on the suction side of the pump.

TUBERCULATION (too-BURR-que-LAY-shun) TUBERCULATION

The development or formation of small mounds of corrosion products (rust) on the inside of iron pipe. These mounds (tubercules) increase the roughness of the inside of the pipe thus increasing resistance to water flow (decreases the C Factor).

WATER AUDIT WATER AUDIT

A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

CHAPTER 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 1 of 4 Lessons)

5.0 NEED FOR SYSTEM OPERATION AND MAINTENANCE

Chapter 3 reviewed the design, construction, and installation of distribution system facilities, while Chapter 4 examined the water quality problems found in distribution systems and how they originate. In this chapter, consideration is given to operation and maintenance procedures needed to reliably assure the delivery of sufficient water at adequate pressures, and prevent or minimize water quality degradation. Operation and maintenance are on-going daily concerns, in addition to emergency situations, as a never-ending job for water distribution system operators. Unless they are performed systematically, properly and on a timely basis, problems in a system will get worse. The water supplier's management and operators have the legal responsibility for delivering a safe water to their customers and this is largely done through the conscientious operation and maintenance of the system facilities.

Both preventive and corrective maintenance are necessary. Preventive maintenance is that which is specifically scheduled; while corrective maintenance (repairs) is not scheduled, but is done after the appearance of a problem which must be corrected to continue satisfactory operation. A planned distribution system preventive maintenance program must be incorporated into every water utility's operation. This maintenance program insures the safety of the water and results in fewer interruptions of service and fewer consumer complaints. The objective of maintenance is the *MAXIMUM CONTINUOUS SERVICE OF THE EQUIPMENT IN THE SYSTEM AT THE LOWEST POSSIBLE COST TO THE UTILITY.* A schedule for routine preventive maintenance should be prepared for *ALL* utility equipment. Operators should be required to follow the prepared schedule and document the work they do.

Also needed are proper and specific operational procedures for inspecting, monitoring, testing, repairing, and disinfecting a system, as well as for locating underground facilities and other activities that are done more or less on a routine basis. Weak links in the system must be detected and eliminated. System records must be sufficient to document the system facilities, their condition, the routine maintenance that should be done, all maintenance that has been done, the problems that have been found and corrective measures that were taken.

Routine and emergency operating procedures should be in writing and clear to all operators with the authority to act in emergencies. Frequent training or refresher courses for all operators will help keep them familiar with the procedures and equipment for which they are responsible. Proper operation and maintenance will keep the system operating smoothly and will extend the useful life of the facilities.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.0A How do water suppliers meet their legal responsibility for delivering safe water to customers?

5.0B What is the objective of distribution system maintenance?

5.1 SYSTEM SURVEILLANCE

5.10 Purpose of System Surveillance

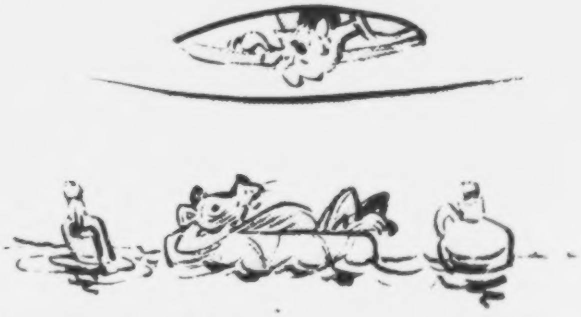
Surveillance of distribution systems is done for three reasons. First, to detect and correct any problems which are sanitary hazards; second, to detect and correct any significant deterioration of facilities or equipment used for the storage and transportation of the water supply; and third, to detect the encroachment of other utilities (sewer, power, gas, phone). Some types of surveillance, such as checking for vandalism, are performed routinely, while others are done only under special circumstances, such as checking for damage after a storm. Generally, routine surveillance in a distribution system would only involve above-ground facilities such as reservoirs, pump stations and valves. However, some less frequent surveillance can also be made of underground facilities as described later in this section.

Critical areas of the distribution system should be patrolled routinely so that the water utility will have an early warning of any adverse conditions that might appear. Any activity or situation which might endanger a water facility or the quality of the water must be investigated and reported without delay. Possible damage from floods, earthquakes, or fires needs to be looked into promptly.

Just as important as routine patrolling is having the field crews watch for actual or potential problems as they attend to their duties. The sooner corrective action is taken after a problem is found, the easier it usually is to make the correction. The longer facilities or water quality deteriorate, the more difficult the situation becomes.

5.11 Treated Water Storage Facilities

Storage facilities in the distribution system are the most obvious facilities needing surveillance. They are generally not under a positive pressure (except for pressure tanks) and are usually above or at ground level. They are, therefore, the most susceptible part of the distribution system to quality degradation from external sources. Open reservoirs are the most critical type of reservoir in this regard, with below-ground reservoirs next in line. Just about anything that one could think of has been found during inspections of reservoirs. For example, cans, bottles, papers, and even a pile of human fecal matter were found on a reservoir ledge inside a covered, 10 million gallon (38,000 cu m) reservoir. Finding small animals, dead or alive, in reservoirs is not uncommon.



Daily surveillance is recommended for trespassing, vandalism, dumping of trash or swimming. Pay particular attention to fence and screen openings, roof damage, intact locks on reservoirs and to manholes or doors. In one case, repeated high bacterial counts occurred and an inspection revealed that a roof manhole was open and several pigeons had entered and drowned in the water. If these daily inspections reveal any change in water color, odor, or turbidity or if any other evidence indicates the water may have been tampered with, take the facility out of service and contact the health department immediately to determine what further action should be taken. Some tests that can be quickly made are chlorine residual, conductance (for TDS), pH and alkalinity. Bacteriological tests take longer to complete, but should also be made (for example, 24-hour coliform tests by the membrane filter method).

Inspect reservoir covers frequently to determine if they are watertight. If a roof develops leaks, any contaminants on the roof, such as bird droppings, will be washed into the reservoir. Even concrete roofs may develop cracks in time and permit leakage. Vent screens should be inspected to assure they are in good condition. If the screens on the vents are torn or rust away, it is obvious that small animals can gain entry to the reservoir. Vent areas must be protected to prevent rain, wind-blown items (leaves, paper), roof drainage, debris and, to the extent possible, dust and dirt from entering the reservoir. Also check the screening on the vertical overflow pipes. In one case, the remains of two decomposed rodents were found in a tank which the rodents apparently had crawled into through an unscreened vertical overflow pipe some 20 ft (6 m) high.

Other reservoir inspections may be made at less frequent intervals. Weekly or more frequent inspections are advisable to note any algae, slime and/or worm growths; floating or settled materials; or deterioration of roofing (corrosion or dry rot) and wooden trusses. At least twice a year, the interior of each storage tank should be inspected to determine the condition of the interior coating and whether the tank needs to be washed out, completely cleaned, or recoated. Interior inspections may also reveal the presence of animals, birds or debris in the tank. The condition of the vents can be seen quite well from the interior of the tank. Preferably every year, but certainly at least every other year, each reservoir should be drained and thoroughly inspected to determine if there is any significant leakage or corrosion and to observe the nature and amount of sediments on the floor or bottom. Cleaning of the reservoir usually takes place at this time.

After a heavy rainfall, inspect the reservoir for damage. If a below-ground reservoir is located where it could be affected by floods, an inspection should be made during such periods to determine whether or not storm waters are getting into the facility or erosion is undermining the structure.

Routinely inspect any sewers located near below-ground reservoirs to determine if there is any noticeable leakage around them. The possibility exists that leaking wastewater could seep (infiltrate) through the ground and cracks in reservoir walls and reach the stored water. As part of the surveillance made after storms, be alert to possible overflow of wastewater from damaged or overloaded sewers to a reservoir area.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.1A List the elements of surveillance that should be considered in a water distribution system surveillance program.

5.1B Why should critical parts of a distribution system be patrolled on a routine basis?

5.1C What items should be checked during a daily surveillance inspection of a reservoir?

5.1D What items should be checked during weekly inspections of a reservoir?

5.12 Mains

Water utility operators should be on the lookout for signs of unauthorized construction activity or soil erosion on or near the utility's pipelines which may pose a physical threat to the line. All wastewater facilities must be kept a proper distance from the mains or meet special construction requirements as discussed in Chapter 3. An observer from the utility should be present during any digging or excavation (especially blasting) near the mains. Reasonable access to the main must always be maintained; and there should be no construction on the piping right-of-way unless it is authorized by the utility. During the routine work of the field crews, operators should be on the lookout for possible main leaks and report any wet spots, sunken areas, or other unusual conditions.

Even though water mains are located in the ground and out of sight, they still need to be monitored. Valuable information can be obtained by inspecting the condition of the inside of mains when repairs or additions are made to the system, or even by examining pipe cut-outs from main tapping operations. When *TUBERCULATION*[1] or other deposition is found, take samples to the laboratory for analysis or further study to help determine the cause of their formation and to develop remedial treatment measures. Another method for checking pipe conditions is to place test pipe specimens (*COUPONS*[2]) in the distribution system where they can be periodically removed, examined, weighed, photographed, and put back.

5.13 Valves and Blowoffs

Valve boxes and other valve appurtenances should be checked at least annually to determine if they are damaged, filled with earth, or covered over by pavement. Vacuum or air-relief valves ("air-vacs") and blowoffs should be inspected after rains or floods to assure that they are not submerged in drainage waters and that they work properly.

5.14 Customer Services

Meter readers should be alert for any problems noted during their rounds. A periodic check should be made of the condition of the meter or curb box. If a box has been displaced and parts of it project out of the ground, there is a danger of injury resulting from tripping. This has been one of the most frequent sources of lawsuits against utilities. Leaking services should also be noted and reported.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.1E Why should field crews be on the lookout for any unauthorized construction activity or erosion near the utility's pipelines?

5.1F How often should valves and valve boxes be inspected?

5.1G When should air-relief valves be inspected?

5.15 Vandalism

The normal security measures taken to prevent vandalism include locks on doors and gates, fences, lighting, posting and patrolling. These measures will not stop vandalism, but should reduce it. These protective measures must not be ignored and allowed to deteriorate into uselessness (such as a fence with a hole in it).

If vandalism or illegal entry is found, make a thorough investigation to determine what damage might have been done and whether there is any possibility of a threat to the quality of the water supply. Check the appearance and odor of the water supply in the area. Record the condition of all locks, any questionable conditions in the areas where unauthorized entry apparently took place, the presence of hazardous material containers, missing items, and damaged equipment. Contact any neighbors in the area for additional information and request assistance to watch the facility. Then promptly report any damage or questionable conditions you have found to responsible supervisory personnel. If water quality may be affected, the health department should be called immediately. If the questionable part of the system can be isolated, this should be done. Notify customers and the health department if a decision is made to shut down part of the system.

As already noted, if there is any detectable change in color, odor or turbidity of the water, or any other evidence that the water has been tampered with, the facility should be *IMMEDIATELY TAKEN OUT OF SERVICE.* Water quality tests that can be done promptly and would be indicative of suspected contamination should be promptly run. Tests that can be quickly made are chlorine residual, conductance (for TDS, pH, and alkalinity. Bacteriological tests take longer to complete, but should also be made (for example, 24-hour coliform tests by the membrane filter method).

Fortunately, most acts of vandalism cause only superficial damage and do no serious harm. Water quality safeguards against minor vandalism are built into most systems and their operation. Existing chlorine residuals will assist in minimizing any threat from disease organisms. A large dilution factor is normally present which will also minimize any contamination threat. Routine sampling and continuous water quality monitoring assist in revealing any possible threat to water quality. For example, telemetering of chlorine residuals and turbidity can indicate water quality problems. Similarly, telemetering of pressures, flows, and reservoir levels can help detect operational problems early.

Automatic controls will often compensate for or minimize certain acts of vandalism. The fact that most of the distribution system is underground and relatively inaccessible makes only a small portion of the system actually vulnerable. Reservoirs which may have been contaminated can usually be readily isolated as reserve supplies of water are often available from other sources. "Looped" distribution lines will allow the isolation of problem areas. Finally, the consumer can be counted upon to quickly report any perceived change in water appearance, taste, or odor.

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[1] *Tuberculation (too-BURR-que-LAY-shun). The development or formation of small mounds of corrosion products (rust) on the inside of iron pipe. These mounds (tubercules) increase the roughness of the inside of the pipe thus increasing resistance to water flow (decreases the C Factor).*

[2] *Coupon. A steel specimen inserted into water to measure the corrosiveness of water. The rate of corrosion is measured as the loss of weight of the coupon (in milligrams) per surface area (in square decimeters) exposed to the water per day. See Figure 5.47, page 252.*
10 decimeters = 1 meter = 100 centimeters

If the vandal is still present and does not leave, notify the authorities (supervisor, police) immediately. *DO NOT ATTEMPT TO USE FORCE* on a vandal, even a child, because you or the vandal could be injured. After the episode is over, make a complete written report describing the vandalism (including photos) and its actual and potential effects on the physical system and water quality.

5.16 Telemetering

Some types of surveillance can also be accomplished by using remote indicating or recording systems. Remote control of a function usually involves telemetering. Quite simply, this involves the measuring, transmitting, and receiving of data at a distance via phone lines, radio or microwave. Indicating or recording gages can be mounted at any convenient place, or a number of them can be put together on a central control panel and can show many different types of data, such as water elevations in reservoirs or tanks, rate of discharge or pumps, pressures in mains at any distant point, and rate of flow. Telemetered water quality data might also include residual chlorine, turbidity, and/or other water quality indicators. Strip charts or circular chart recorders may be used to record telemetered signals. Telemetering also can be used to start and stop pumps and open and close valves.

5.17 Other Surveillance

Water quality monitoring and cross-connection control, which are discussed in the following sections of this chapter, can also be an important part of a utility's distribution system surveillance program.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.1H What should be done if vandalism or illegal entry is discovered?

5.1I What water quality tests could be conducted immediately after an act of vandalism or illegal entry is discovered?

5.1J What should an operator do if a vandal is discovered in a water distribution system facility?

5.1K Give examples of information which can be telemetered.

5.2 WATER QUALITY MONITORING

5.20 Purpose of Water Quality Monitoring

A properly designed and meaningful water quality monitoring program is needed for each water utility. Monitoring is not just done to comply with the requirements of regulatory agencies, but also to:

1. Establish the safety and potability of the supply by determining if it meets standards,
2. Provide a record of the quality of the water served,
3. Assist in determining the source of any contamination which might have reached the system,
4. Check the quality of the water to be served after installation, cleaning or repair of mains and reservoirs,
5. Detect any changes in quality between the source and consumer's system (to determine if there is deterioration of the water after it has gone through the distribution system),
6. Answer consumer questions,
7. Verify or refute complaints,
8. Solve special problems such as those resulting from corrosion or encrustation, and
9. Assist in tracing the flow of water through the distribution system.

5.21 Monitoring Program

Many water quality monitoring programs are based on the requirements of the United States National Interim Primary Drinking Water Regulations. A summary of these regulations, as prepared by the United States Environmental Protection Agency (USEPA) is given in the poster inserted inside the back cover of this manual. This poster shows the contaminants to be tested, maximum contaminant levels (MCLs), monitoring requirements, and procedures to be followed when there is a failure to meet standards or otherwise comply with them. The monitoring requirements given are the *MINIMUM* that must be followed. Water suppliers should not hesitate to take more and should collect as many samples as necessary to clearly prove the quality of water being served throughout the system or to solve a quality problem. Requirements for total trihalomethanes apply to community water systems which chlorinate their supplies and serve 10,000 or more people. Generally, four samples per water treatment plant must be collected every three months. An MCL of 0.10 mg/*L* must be met based on a running annual average of the quarterly samples (see EXAMPLES 1, 2 and 3 at the end of this section).

National Secondary Drinking Water Regulations have been established for contaminants that may adversely affect the aesthetic quality of the drinking water and result in consumer rejection of the water provided. The poster lists these contaminants and their MCLs. The secondary standards are not federally enforceable, but are intended as guidelines for the States. The States have been encouraged to implement these regulations so that the public will not seek to obtain drinking water from potentially lower quality, higher risk sources. The regulations recommend that these contaminants be monitored at intervals no less frequent than the monitoring performed for the inorganic chemical contaminants listed in the National Interim Primary Drinking Water Regulations.

Additional routine sampling is needed where sanitary hazards exist or whenever levels of contaminants approach or exceed maximum contaminant levels. Provisions of a minimum monitoring program and compliance with the quality standards are not in themselves sufficient evidence that protection of the water in the distribution system is adequate. The overall operation and maintenance procedures used by the utility and results of inspections of the physical facilities (called *"SANITARY SURVEYS"*[3]) must be considered along with the quality analyses to evaluate the adequacy of protection of the supply.

Sampling should be done in accordance with accepted collection and transportation procedures. In addition, it will be necessary to test enough samples to provide an optimum amount of information on the quality of the water being supplied. Details on collection and transportation of samples are given in Chapter 7, "Laboratory Procedures," in **SMALL WATER SYSTEM OPERATION AND MAINTENANCE**.

FORMULAS

To calculate an average measurement for a time period or a group of measurements or observations, add up all of the measurements and divide by the number of measurements.

$$\text{Average} = \frac{\text{Sum of All Measurements}}{\text{Number of Measurements}}$$

The Safe Drinking Water Act requires that total trihalomethanes be calculated as quarterly averages as shown above. When the running annual average exceeds the MCL of 0.10 mg/*L*, the value should be reported to the state within 48 hours. The running annual average is calculated by using the quarterly average for the quarter being considered and the three quarters immediately before the one being considered.

$$\text{Annual Running Average} = \frac{\text{Sum of Measurements}}{\text{Number of Measurements}}$$

Running averages are used to "smooth out" data. In the case of THMs, if one quarter was high and exceeded the MCL, the other three quarters could pull the annual running average MCL down and keep the water utility in compliance.

EXAMPLE 1

Four samples of water from a water distribution system were collected and analyzed for total trihalomethanes (TTHMs). Results of the analyses were as follows, 0.07 mg/*L*, 0.05 mg/*L*, 0.04 mg/*L* and 0.08 mg/*L*. What was the quarterly THM average in mg/*L*?

Known

Results from TTHM Analyses

Sample No.	Conc., mg/*L*
1	0.07
2	0.05
3	0.04
4	0.08

Unknown

Quarterly TTHM Average, mg/*L*

Formula for calculating average values:

$$\text{Average} = \frac{\text{Sum of All Measurements}}{\text{Number of Measurements}}$$

Calculate the quarterly TTHM average for the months of January, February and March.

$$\begin{aligned}\text{Average TTHM, mg}/L &= \frac{\text{Sum of Measurements, mg}/L}{\text{Number of Measurements}}\\ &= \frac{0.07\text{ mg}/L + 0.05\text{ mg}/L + 0.04\text{ mg}/L + 0.08\text{ mg}/L}{4}\\ &= \frac{0.24\text{ mg}/L}{4}\\ &= 0.06\text{ mg}/L\end{aligned}$$

EXAMPLE 2

Quarterly TTHM average values for year one are given. Calculate the annual average. First quarter (January, February and March), 0.06 mg/*L*; second quarter (April, May and June), 0.08 mg/*L*; third quarter (July, August and September), 0.11 mg/*L*; and fourth quarter (October, November and December), 0.09 mg/*L*.

Known

Results from Quarterly TTHM Analyses

Quarter	Conc., mg/*L*
1	0.06
2	0.08
3	0.11
4	0.09

Unknown

Annual TTHM Average, mg/*L*

Calculate the annual TTHM average for the year.

$$\begin{aligned}\text{Annual Average TTHM, mg}/L &= \frac{\text{Sum of Measurements, mg}/L}{\text{Number of Measurements}}\\ &= \frac{0.06\text{ mg}/L + 0.08\text{ mg}/L + 0.11\text{ mg}/L + 0.09\text{ mg}/L}{4}\\ &= \frac{0.34\text{ mg}/L}{4}\\ &= 0.085\text{ mg}/L\end{aligned}$$

EXAMPLE 3

Determine the annual running TTHM average using the results in Example 2 if the results during the next year were as follows: first quarter, 0.08 mg/*L*; second quarter, 0.09 mg/*L*; third quarter, 0.14 mg/*L*; and fourth quarter, 0.08 mg/*L*.

Known

Results of Quarterly TTHM Analyses

Year 1

Quarter	Conc., mg/*L*
1	0.06
2	0.08
3	0.11
4	0.09

Unknown

Annual Running TTHM Average, mg/*L*

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[3] *Sanitary Survey. A detailed evaluation and/or inspection of a source of water supply and all conveyances, storage, treatment and distribution facilities to insure its protection from all pollution sources.*

Year 2	
1	0.08
2	0.09
3	0.14
4	0.08

Calculate the annual running TTHM average for each quarter during the Year 2. Use the quarterly TTHM average for the quarter being considered and the three quarters immediately before the one being considered.

Year 2, Quarter 1

$$\begin{aligned}\text{Annual Running TTHM Average, mg/}L &= \frac{\text{Sum of Measurements, mg/}L}{\text{Number of Measurements}}\\ &= \frac{0.08\text{ mg/}L + 0.09\text{ mg/}L + 0.11\text{ mg/}L + 0.08\text{ mg/}L}{4}\\ &= \frac{0.36\text{ mg/}L}{4}\\ &= 0.09\text{ mg/}L\end{aligned}$$

Year 2, Quarter 2

$$\begin{aligned}\text{Annual Running TTHM Average, mg/}L &= \frac{0.09\text{ mg/}L + 0.08\text{ mg/}L + 0.09\text{ mg/}L + 0.11\text{ mg/}L}{4}\\ &= \frac{0.37\text{ mg/}L}{4}\\ &\quad 0.093\text{ mg/}L\end{aligned}$$

Year 2, Quarter 3

$$\begin{aligned}\text{Annual Running TTHM Average, mg/}L &= \frac{0.14\text{ mg/}L + 0.09\text{ mg/}L + 0.08\text{ mg/}L + 0.09\text{ mg/}L}{4}\\ &= \frac{0.40\text{ mg/}L}{4}\\ &\quad 0.10\text{ mg/}L\end{aligned}$$

Year 2, Quarter 4

$$\begin{aligned}\text{Annual Running TTHM Average, mg/}L &= \frac{0.08\text{ mg/}L + 0.14\text{ mg/}L + 0.09\text{ mg/}L + 0.08\text{ mg/}L}{4}\\ &= \frac{0.39\text{ mg/}L}{4}\\ &\quad 0.098\text{ mg/}L\end{aligned}$$

SUMMARY OF RESULTS FOR YEAR 2

Quarter	Quarterly TTHM Average, mg/*L*	Annual Running TTHM Average, mg/*L*
1	0.08	0.090
2	0.09	0.093
3	0.14	0.100
4	0.08	0.098

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.2A Requirements for total trihalomethanes apply to community water sysems which chlorinate their water supplies and serve ____ or more people.

5.2B National Secondary Drinking Water Regulations apply to what types of contaminants?

5.2C Under what conditions should more samples be collected than the minimum required by the National Interim Primary Drinking Water Regulations?

5.22 Sampling Location

Ordinarily routine samples to analyze for primary and secondary contaminants are drawn from system sources of supply unless it appears there could be some change in constituent levels in the distribution system. Routine nonsource sampling performed by utilities includes the following:

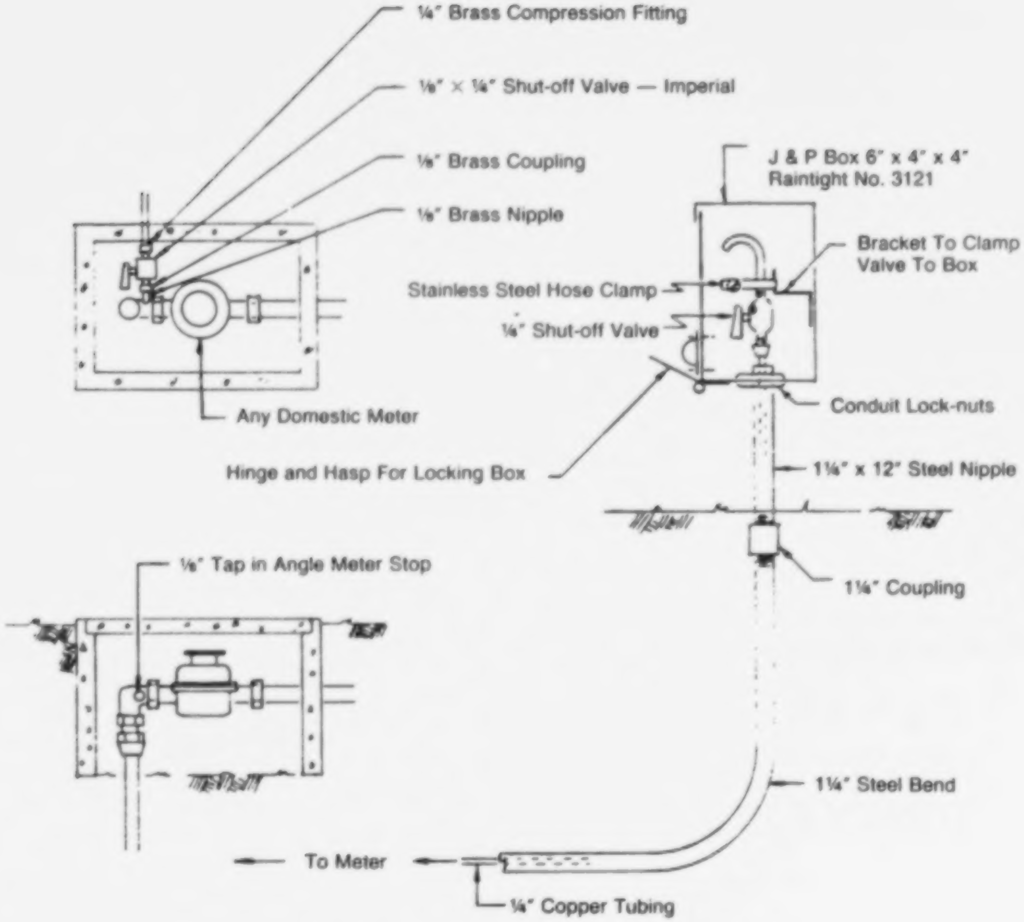
1. Bacteriological samples (for coliforms) are taken at points which are representative of the conditions within the distribution system. Be sure the sample bottles contain sodium thiosulfate to neutralize the chlorine residual. Measure the chlorine residual when the sample is collected.
2. Turbidity samples are taken at representative source entry points to the water distribution system.
3. For total trihalomethane sampling, 25 percent of the samples are collected at extreme ends of the distribution system and 75 percent at locations representative of population distribution.
4. Chlorine residuals are frequently collected at the most remote locations of the distribution system to insure that a chlorine residual exists throughout the entire system. Samples are also collected and tested for chlorine residual throughout the system.
5. Where tastes, odors and color may be a problem, samples are often taken at representative or critical points in the distribution system. Such sampling may continue until there is adequate demonstration no problem exists. Critical points would include dead ends and other areas where water movement is slow, and areas where corrosion problems would be expected.

When samples are collected from the distribution system, they normally are taken from representative points throughout the system. Local conditions at a specific sample tap and in the piping connection to the main may make the sample point unrepresentative of the quality of the water being furnished to the consumers. The best and truest evaluation of water quality can be obtained from samples drawn *DIRECTLY* from the main at specially designed sampling stations.

Establishment by the utility of a specially designed distribution system sampling station, such as that in Figure 8.1, is recommended. The design should include a housing enclosing a single gooseneck sampling tap, a direct connection to the main being sampled with the shortest pipe possible (use pipe made of corrosion-resistant material), and a drip valve to drain the sampling tap when it is shut down.

5.23 Bacteriological Sampling

Most of the effort in water quality monitoring programs is spent in collecting routine samples for bacteriological analysis. A detailed discussion on bacteriological sampling procedures is provided in Chapter 11, "Laboratory Procedures." **SMALL WATER SYSTEM OPERATION AND MAINTENANCE.**


¼" Brass Compression Fitting
⅛" × ¼" Shut-off Valve — Imperial
⅛" Brass Coupling
⅛" Brass Nipple
J & P Box 6" x 4" x 4"
Raintight No. 3121
Bracket To Clamp
Valve To Box
Stainless Steel Hose Clamp
¼" Shut-off Valve
Any Domestic Meter
Conduit Lock-nuts
Hinge and Hasp For Locking Box
1¼" x 12" Steel Nipple
⅛" Tap in Angle Meter Stop
1¼" Coupling
1¼" Steel Bend
To Meter
¼" Copper Tubing

NOTE: Box should be located near a stationary object, such as power pole, for protection, or place sufficient concrete around riser below ground.

Fig. 5.1 Sampling station

(Source: *DISTRIBUTION SYSTEM BACTERIOLOGICAL SAMPLING AND CONTROL GUIDELINES*, published by California-Nevada Section AWWA)

5.24 Chlorine Residual Testing

Many utilities attempt to maintain a chlorine residual throughout the distribution system. Chlorine is very effective in biological control and especially in elimination of coliform bacteria from the finished water. Adequate control of coliform "aftergrowth" is usually obtained only when chlorine residuals are carried to the farthest points of the distribution system. To assure that this is taking place, make daily chlorine residual tests. A residual of about 0.2 mg/*L* measured at the extremities of the system is usually a good indication that a free chlorine residual is present in all other parts of the system. This small residual can destroy a small amount of contamination, so a lack of chlorine residual could indicate the presence of heavy contamination. If routine checks at a given point show measurable residuals, any sudden absence of a residual at that point should alert the water supplier to the possibility that a potential problem has arisen which needs prompt investigation. Immediate action that can be taken includes retesting for chlorine residual, then checking chlorination equipment and finally search for a source of contamination which could cause an increase in the chlorine demand.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.2D Samples are routinely collected from a water distribution system for what kinds of tests?

5.2E Why do utilities attempt to maintain chlorine residuals throughout the distribution system?

5.2F What should an operator do if a sudden absence of a chlorine residual is discovered in a water distribution system?

5.3 CROSS—CONNECTION CONTROL

5.30 Importance of Cross-Connection Control

BACKFLOW[4] of contaminated water through cross-connections into community water systems is not just a theoretical problem, As noted in Chapters 3 and 4, contamination through cross-connections has consistently caused more waterborne disease outbreaks in the United States than any other reported factor. Inspections have often disclosed numerous unprotected cross-connections between public water systems and other piped systems on consumers' premises which might contain wastewater; stormwater; processed waters (containing a wide variety of chemicals); and untreated supplies from private wells, streams, and ocean waters. Therefore, an effective cross-connection control program is essential.

Backflow results from either *BACK PRESSURE*[5] or *BACKSIPHONAGE*[6] situations in the distribution system. Back pressure occurs when the user's water supply is at a higher pressure than the public water supply system (Figure 5.2). Typical locations where back pressure problems could develop include services to premises where wastewater or toxic chemicals are handled under pressure or where there are unapproved auxiliary water supplies such as a private well or the use of surface water or sea water for fire fighting. Backsiphonage is caused by the development of negative or below atmospheric pressures in the water supply piping (Figure 5.3). This condition can occur when there are extremely high water demands (fire fighting), water main breaks, or the use of on-line booster pumps.

The best way to prevent backflow is to permanently eliminate the hazard. Back pressure hazards can be eliminated by severing (eliminating) any direct connection at the pump causing the back pressure with the domestic water supply system. Another solution to the problem is to require an air-gap separation device (Figure 5.6, page 199) where the water supply service line connects to the private system under pressure from the pump. To eliminate or minimize backsiphonage problems, proper enforcement of plumbing codes and improved water distribution and storage facilities will be helpful. As an additional safety factor for certain selected conditions, a double check valve (Figure 5.7, page 199), may be required at the meter.

5.31 Program Responsibilities

Responsibilities in the implementation of cross-connection control programs are shared by water suppliers, water users (businesses and industries), health agencies, and plumbing officials. The water supplier is responsible for preventing contamination of the public water system by backflow. This responsibility begins at the source, includes the entire distribution system, and ends at the user connection. To meet this responsibility, the water supplier must issue (promulgate) and enforce needed laws, rules, regulations, and policies. Water service should not be provided to premises where the strong possibility of an unprotected cross-connection exists. The essential elements of a water supplier cross-connection control program are discussed in the next section.

The water user is responsible for keeping contaminants out of the potable water system on the user's premises. When backflow prevention devices are required by the health agency or water supplier, the water user must pay for the installation, testing, and maintenance of the approved devices. The user is also responsible for preventing the creation of cross-connections through modifications of the plumbing system on the premises. The health agency or water supplier may, when necessary, require a water user to designate a water supervisor or foreman to be responsible for the cross-connection control program within the water user's premises.

The local or state health agency is responsible for issuing and enforcing laws, rules, regulations and policies needed to control cross-connections. Also the health agency must have a program that assures maintenance of an adequate cross-connection control program and protection of the system on the user's premises is provided where needed by the water utilities.

The plumbing agency (building inspectors) is responsible for the enforcement of building regulations relating to prevention of cross-connections on the user's premises.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 275.

5.3A What has caused more waterborne disease outbreaks in the United States than any other reported factor?

5.3B Who is usually responsible for the implementation of cross-connection control programs?

5.3C What is the water user's cross-connection control responsibility?

5.32 Water Supplier Program

The following elements should be included in each water supplier's cross-connection control program:

1. Enactment of an ordinance providing enforcement authority if the supplier is a governmental agency, or

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[4] *Backflow. A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than the supply intended.*

[5] *Back Pressure. A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.*

[6] *Backsiphonage. A form of backflow caused by a negative or below atmospheric pressure within a water system.*

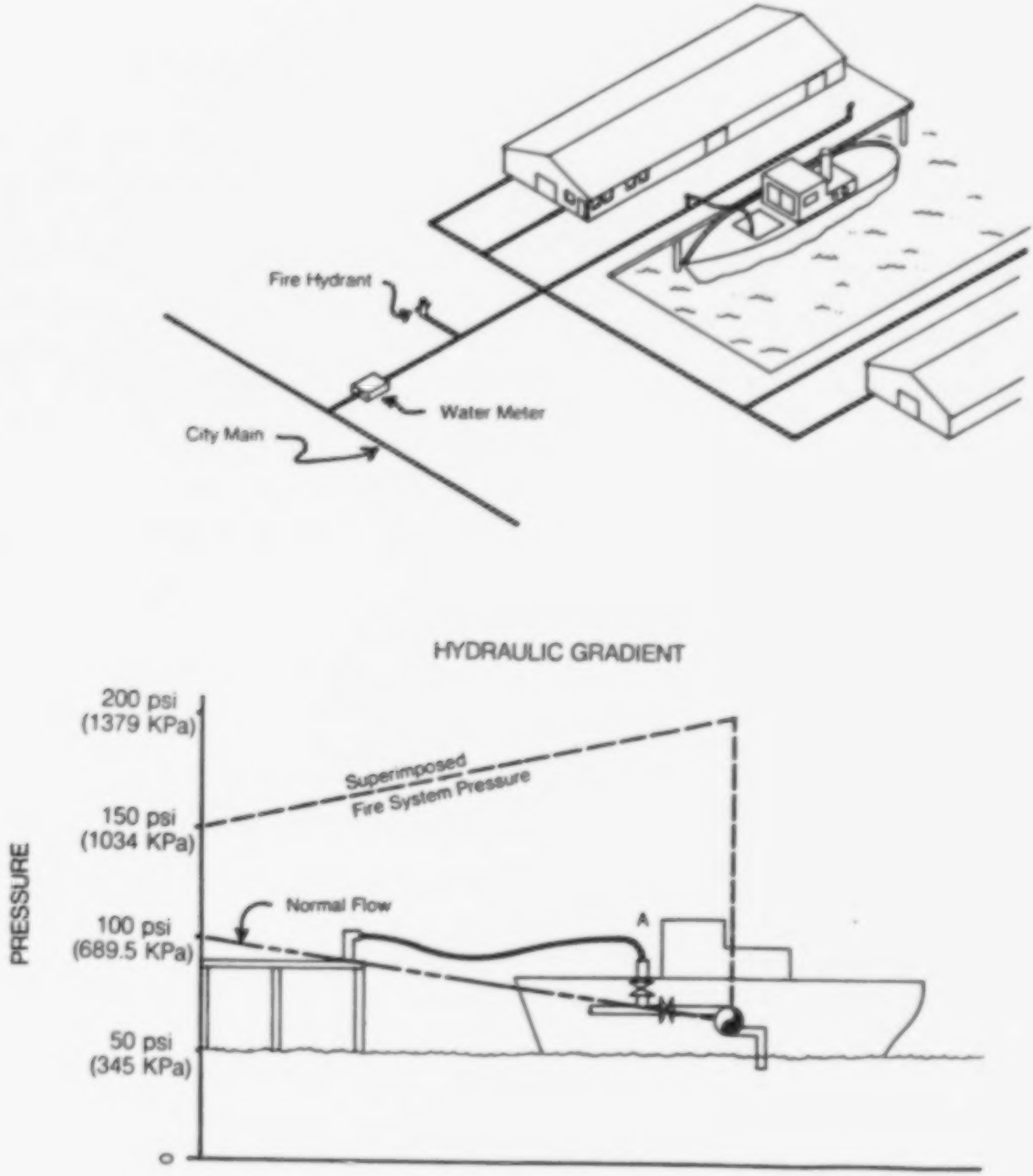
Fire Hydrant
Water Meter
City Main
HYDRAULIC GRADIENT
PRESSURE
200 psi (1379 KPa)
150 psi (1034 KPa)
100 psi (689.5 KPa)
50 psi (345 KPa)
0
Superimposed Fire System Pressure
Normal Flow
A

Fig. 5.2 Backflow due to back pressure

(Source: *MANUAL OF CROSS-CONNECTION CONTROL PROCEDURES AND PRACTICES*, Sanitary Engineering Branch, California Department of Health Services, Berkeley, California)

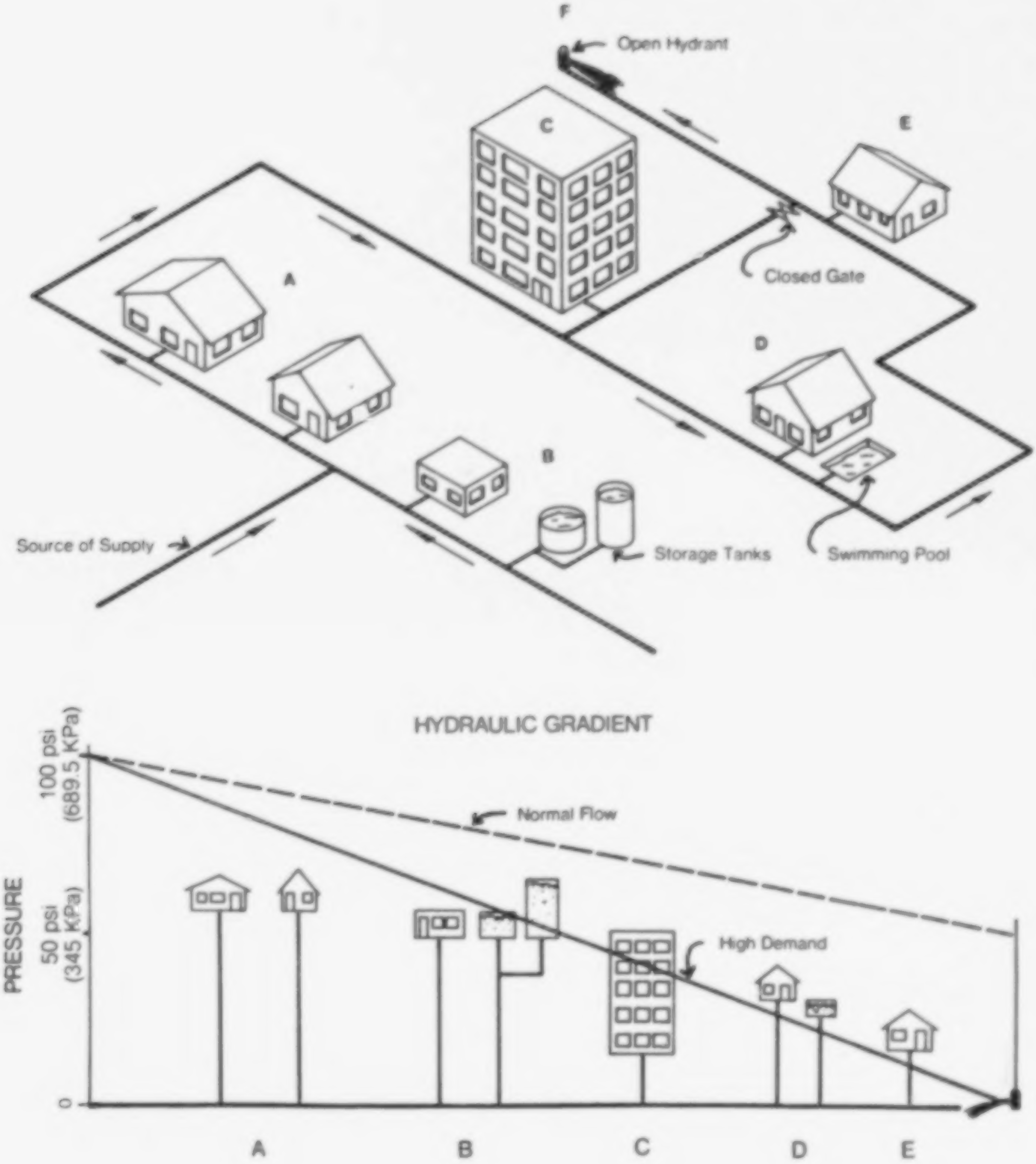
F
Open Hydrant
C
E
Closed Gate
A
D
B
Source of Supply
Storage Tanks
Swimming Pool
HYDRAULIC GRADIENT
100 psi
(689.5 KPa)
Normal Flow
PRESSURE
50 psi
(345 KPa)
High Demand
0
A
B
C
D
E

Fig. 5.3 Backsiphonage due to extremely high water demand
(Source: *MANUAL OF CROSS-CONNECTION CONTROL PROCEDURES AND PRACTICES,* Sanitary Engineering Branch, California Department of Health Services, Berkeley, California)

enactment of appropriate rules of service if the system is investor-owned.[7]

2. Training of personnel on the causes of and hazards from cross-connections and procedures to follow for effective cross-connection control.
3. Listing and inspection or re-inspection on a priority basis of all existing facilities where cross-connections are of concern. A typical cross-connection survey form is shown in Figure 5.4.
4. Review and screening of all applications for new services or modification of existing services for cross-connection hazards to determine if backflow protection is needed.
5. Obtaining a list of approved backflow prevention devices and a list of certified testers, if available.
6. Acceptable installation of the proper type of device needed for the specific hazard on the premises.
7. Routine testing of installed backflow prevention devices as required by the health agency or the water supplier. Contact the health agency for approved procedures.
8. Maintenance of adequate records for each backflow prevention device installed, including records of inspection and testing. A typical form is shown in Figure 5.5.
9. Notification of each water user when a backflow prevention device has to be tested. This should be done after installation or repair of the device and at least once a year.
10. Maintenance of adequate pressures throughout the distribution system at all times to minimize the hazards from any undetected cross-connections which may exist.

All field personnel should be constantly alert for situations where cross-connections are likely to exist, whether protection has been installed or not. An example is a contractor using a fire hose from a hydrant to fill a tank truck for dust control or the jetting (for compaction) of pipe trenches. Operators should especially be on the lookout for illegal bypassing of installed backflow prevention devices.

5.33 Types of Backflow Prevention Devices

Different types of backflow prevention devices are available. The particular type of device most suitable for a given situation depends on the degree of health hazard, the probability of backflow occurring, the complexity of the piping on the premises and the probability of the piping being modified. The higher the assessed risk due to these factors the more reliable and positive the type of device needed. The types of devices normally approved are listed below according to the degree of assessed risk, with the type of device providing the greatest protection listed first. Only the first three devices are approved for use at service connections.

1. Air-gap separation.
2. Reduced pressure principle (RPP) device.
3. Double check valve.
4. Pressure vacuum breaker (only used for internal protection on the premises).
5. Atmospheric (non-pressure) vacuum breaker.

Figure 5.6 shows a typical air-gap separation device and its recommended location. Figure 5.7 shows the installation of a typical double check valve backflow prevention device. These devices are normally installed on the water user's side of the connection to the utility's system and as close to the connection as practical. Figure 5.8 shows a typical installation of pressure vacuum breakers.

Only backflow prevention devices that have passed both laboratory and field evaluations by a recognized testing agency and that have been accepted by the health agency and the water supplier should be used.

5.34 Devices Required for Various Types of Situations

The state or local health agency should be contacted to determine the actual types of devices acceptable for various situations inside the consumer's premises. However, the types of devices generally acceptable for particular situations can be mentioned.

An air gap or a reduced pressure principle (RPP) device is normally required at services to wastewater treatment plants, wastewater pumping stations, reclaimed water reuse areas, areas where toxic substances in toxic concentrations are handled under pressure, and premises having an auxiliary water supply which is or may be contaminated. The ultimate degree of protection is also needed in cases where fertilizer, herbicides or pesticides are injected into a sprinkler system.

A double check valve device should be required when a moderate hazard exists on the premises or where an auxiliary supply exists, but adequate protection on the premises is provided.

Atmospheriic and pressure vacuum breakers are usually required for irrigation systems; however, they are not adequate in situations where they may be subject to back pressure. If there is a possibility of back pressure, a reduced pressure principle device is needed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.3D What items should be included on a cross-connection survey form?

5.3E What factors should be considered when selecting a backflow prevention device?

5.3F Air gap or reduced pressure principle backflow prevention devices are installed under what conditions?

5.4 SYSTEM PRESSURES

A main concern in operation of a water distribution system is the maintenance of a *CONTINUOUS POSITIVE PRESSURE* at all times to all customers. This is necessary not only to meet the flow needs of the customers, but to prevent contamination from backflow. The water supplier should try to maintain a minimum pressure of 35 psi (241 kPa or 2.45 kg/sq cm) at all points in the distribution system, with an absolute minimum of 20 psi (138 kPa or 1.4 kg/sq cm) even during fire flows. In commercial districts, pressures of 75 psi (517 kPa or 5.3 kg/sq cm) and higher are used, but the

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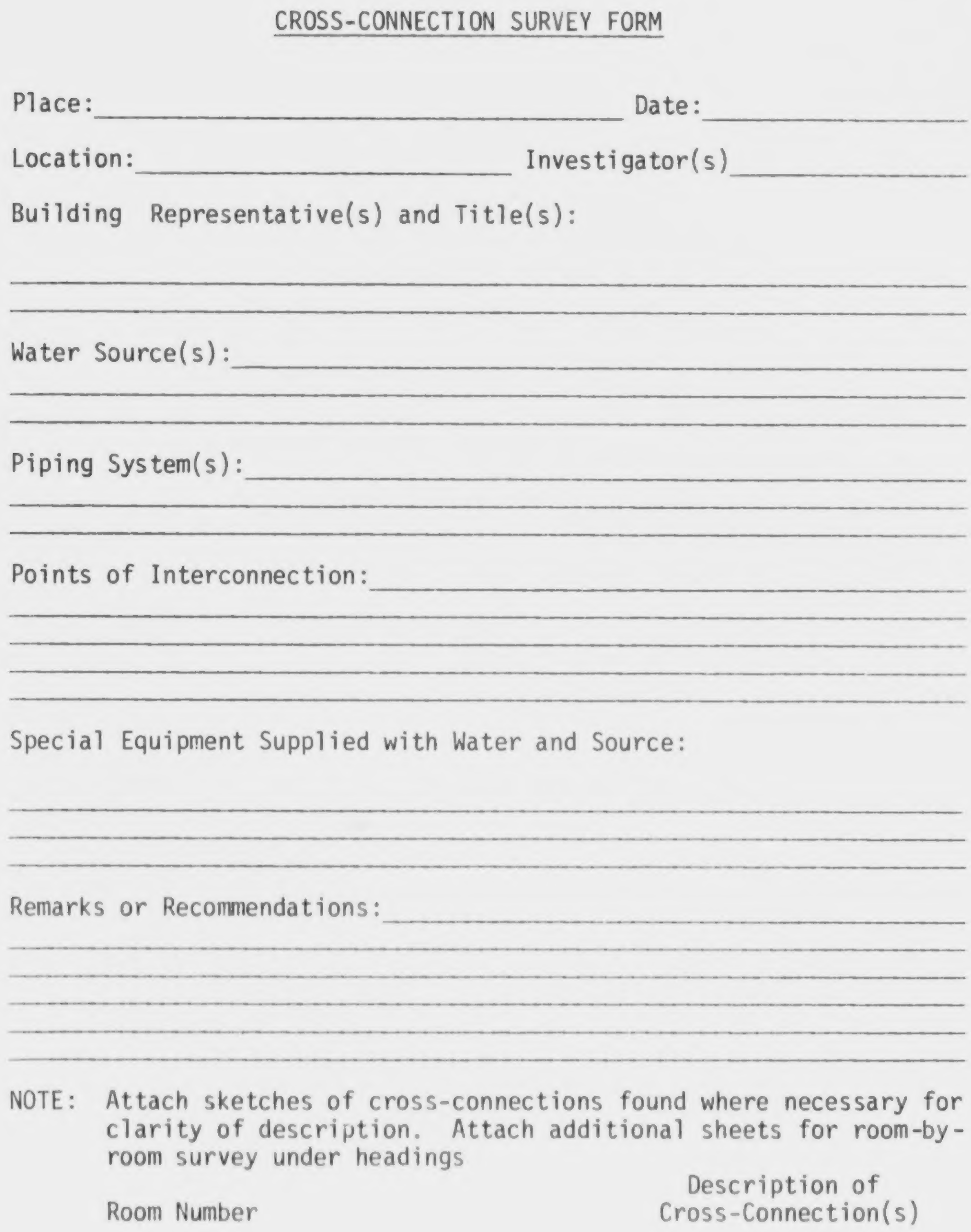
[7] *A typical ordinance is available in CROSS-CONNECTION CONTROL MANUAL, available from ORD Publications, Center for Environmental Research Information, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.*



CROSS-CONNECTION SURVEY FORM

Place: ______________________ Date: ______________

Location: ____________________ Investigator(s) ______________

Building Representative(s) and Title(s):

Water Source(s): ______________________

Piping System(s): ______________________

Points of Interconnection: ______________________

Special Equipment Supplied with Water and Source:

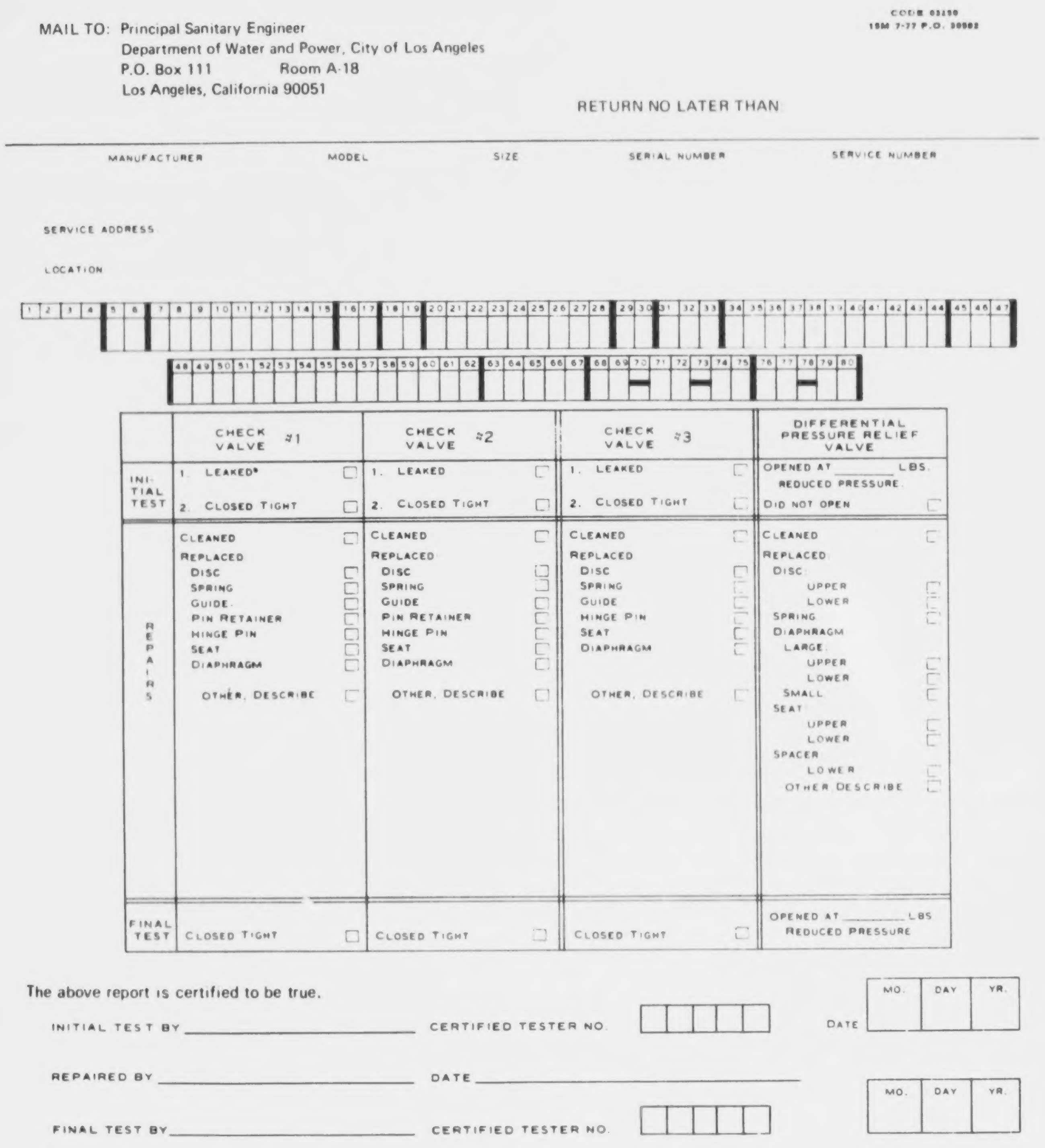
Remarks or Recommendations: ______________________

NOTE: Attach sketches of cross-connections found where necessary for clarity of description. Attach additional sheets for room-by-room survey under headings

Room Number	Description of Cross-Connection(s)

Fig. 5.4 Typical cross-connection survey form

(From *CROSS-CONNECTION CONTROL MANUAL*, U.S. Environmental Protection Agency, Water Supply Division)



MAIL TO: Principal Sanitary Engineer
Department of Water and Power, City of Los Angeles
P.O. Box 111 Room A-18
Los Angeles, California 90051

CODE 03150
15M 7-77 P.O. 30502

RETURN NO LATER THAN

MANUFACTURER	MODEL	SIZE	SERIAL NUMBER	SERVICE NUMBER

SERVICE ADDRESS

LOCATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
																						–			–					–		

	CHECK VALVE #1	CHECK VALVE #2	CHECK VALVE #3	DIFFERENTIAL PRESSURE RELIEF VALVE
INITIAL TEST	1. LEAKED* ☐ 2. CLOSED TIGHT ☐	1. LEAKED ☐ 2. CLOSED TIGHT ☐	1. LEAKED ☐ 2. CLOSED TIGHT ☐	OPENED AT ________ LBS. REDUCED PRESSURE. DID NOT OPEN ☐
REPAIRS	CLEANED ☐ REPLACED DISC ☐ SPRING ☐ GUIDE ☐ PIN RETAINER ☐ HINGE PIN ☐ SEAT ☐ DIAPHRAGM ☐ OTHER, DESCRIBE ☐	CLEANED ☐ REPLACED DISC ☐ SPRING ☐ GUIDE ☐ PIN RETAINER ☐ HINGE PIN ☐ SEAT ☐ DIAPHRAGM ☐ OTHER, DESCRIBE ☐	CLEANED ☐ REPLACED DISC ☐ SPRING ☐ GUIDE ☐ HINGE PIN ☐ SEAT ☐ DIAPHRAGM ☐ OTHER, DESCRIBE ☐	CLEANED ☐ REPLACED DISC UPPER ☐ LOWER ☐ SPRING ☐ DIAPHRAGM LARGE UPPER ☐ LOWER ☐ SMALL ☐ SEAT UPPER ☐ LOWER ☐ SPACER LOWER ☐ OTHER DESCRIBE ☐
FINAL TEST	CLOSED TIGHT ☐	CLOSED TIGHT ☐	CLOSED TIGHT ☐	OPENED AT ________ LBS REDUCED PRESSURE

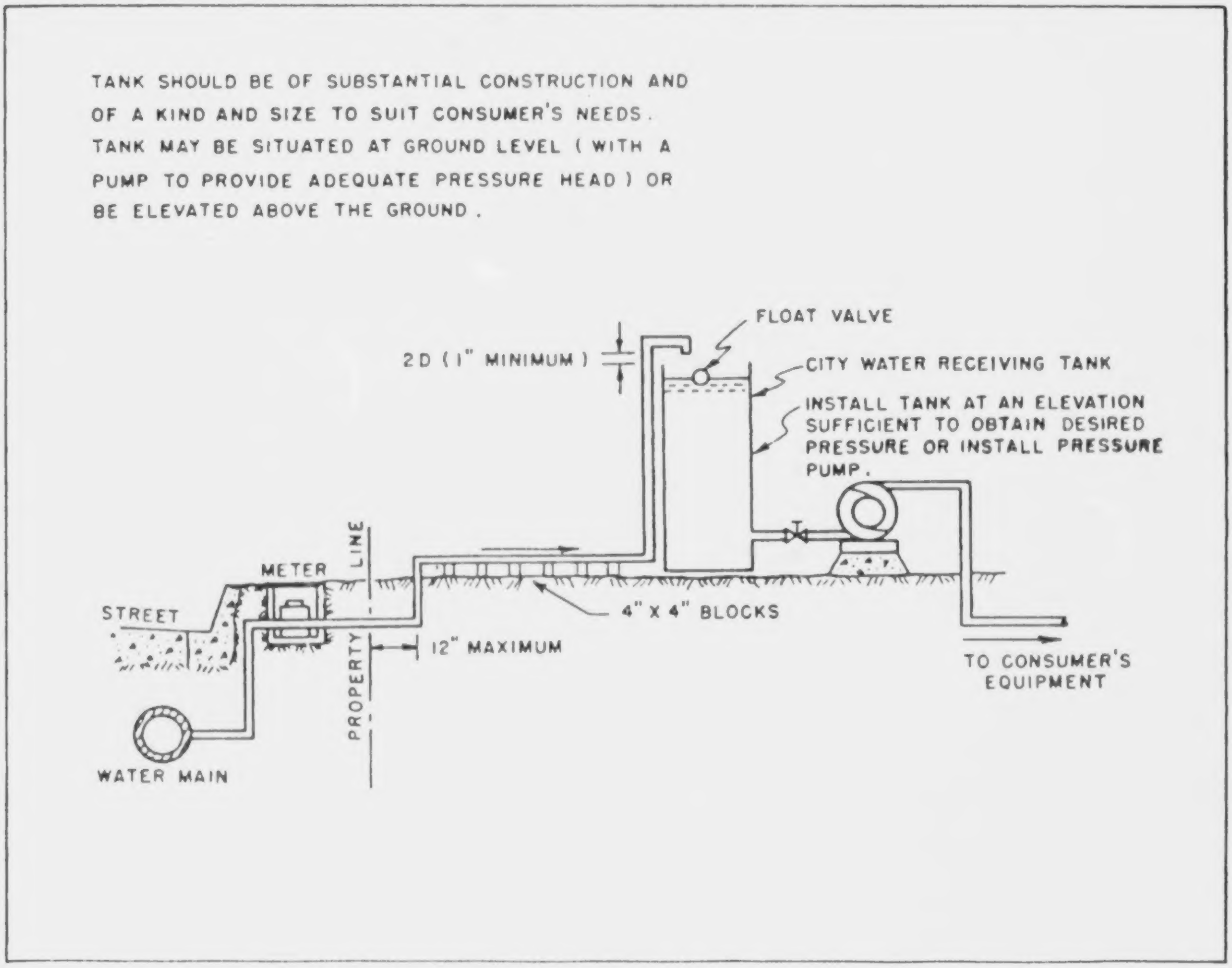
The above report is certified to be true.

INITIAL TEST BY ______________________ CERTIFIED TESTER NO. ☐☐☐☐☐ DATE MO. ☐ DAY ☐ YR. ☐

REPAIRED BY ______________________ DATE ______________________ MO. ☐ DAY ☐ YR. ☐

FINAL TEST BY ______________________ CERTIFIED TESTER NO. ☐☐☐☐☐

Fig. 5.5 Typical backflow prevention device maintenance record form
(Permission of Department of Water and Power, City of Los Angeles)


TANK SHOULD BE OF SUBSTANTIAL CONSTRUCTION AND OF A KIND AND SIZE TO SUIT CONSUMER'S NEEDS. TANK MAY BE SITUATED AT GROUND LEVEL (WITH A PUMP TO PROVIDE ADEQUATE PRESSURE HEAD) OR BE ELEVATED ABOVE THE GROUND.

FLOAT VALVE
2D (1" MINIMUM)
CITY WATER RECEIVING TANK
INSTALL TANK AT AN ELEVATION SUFFICIENT TO OBTAIN DESIRED PRESSURE OR INSTALL PRESSURE PUMP.
METER
PROPERTY LINE
STREET
4" X 4" BLOCKS
12" MAXIMUM
TO CONSUMER'S EQUIPMENT
WATER MAIN

Fig. 5.6 Typical air-gap separation

(From *MANUAL OF CROSS-CONNECTION CONTROL PRACTICES AND PROCEDURES*, California Department of Health Services)

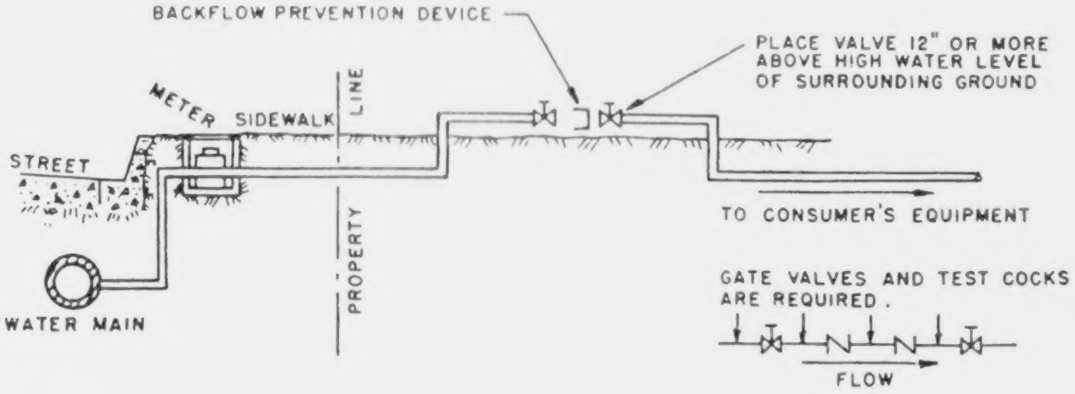

BACKFLOW PREVENTION DEVICE
PLACE VALVE 12" OR MORE ABOVE HIGH WATER LEVEL OF SURROUNDING GROUND
METER
SIDEWALK
PROPERTY LINE
STREET
TO CONSUMER'S EQUIPMENT
WATER MAIN
GATE VALVES AND TEST COCKS ARE REQUIRED.
FLOW

Fig. 5.7 Typical double check valve backflow prevention device

(From *MANUAL OF CROSS-CONNECTION CONTROL PRACTICES AND PROCEDURES*, California Department of Health Services)

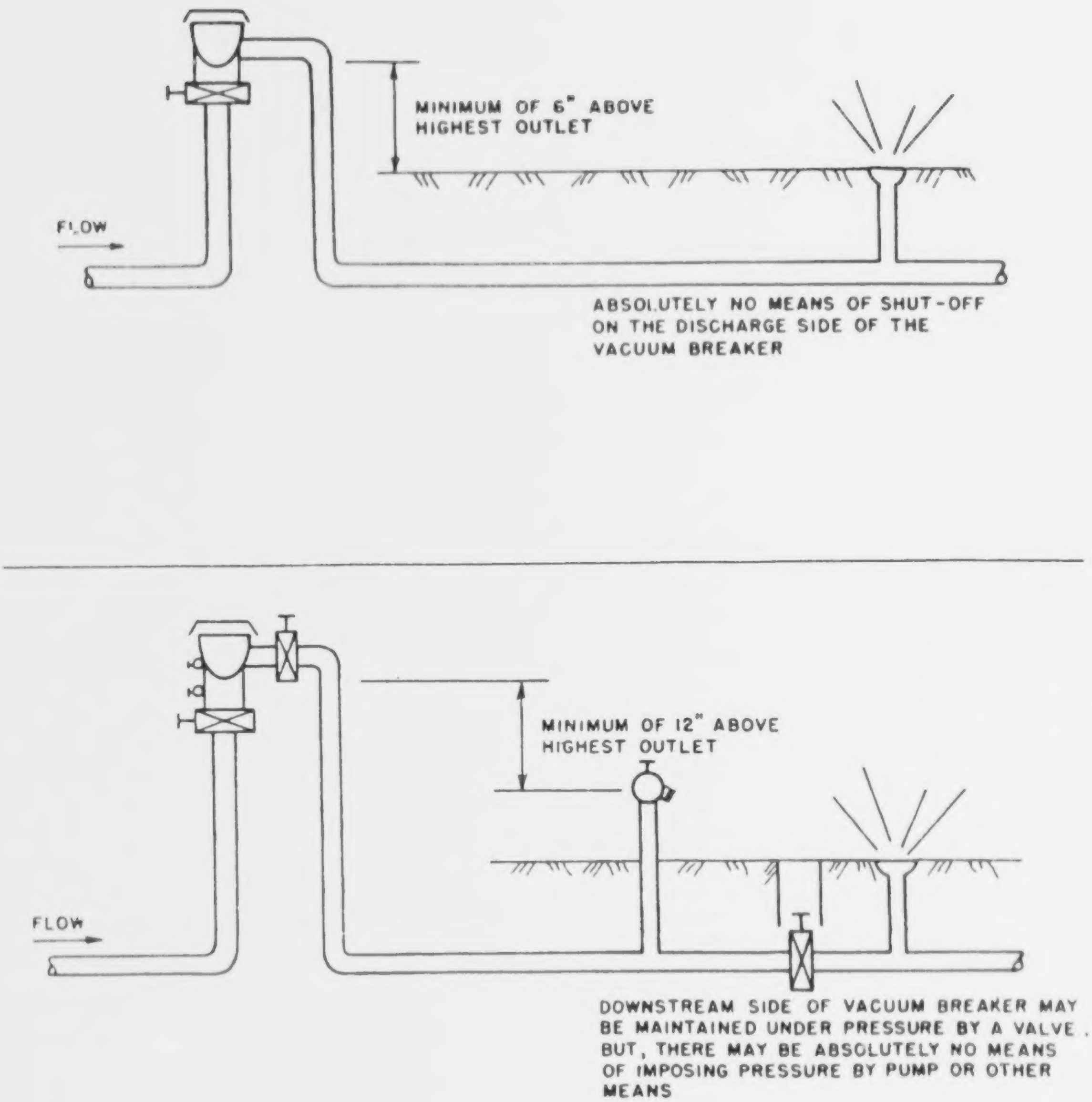

MINIMUM OF 6" ABOVE HIGHEST OUTLET
FLOW
ABSOLUTELY NO MEANS OF SHUT-OFF ON THE DISCHARGE SIDE OF THE VACUUM BREAKER
MINIMUM OF 12" ABOVE HIGHEST OUTLET
FLOW
DOWNSTREAM SIDE OF VACUUM BREAKER MAY BE MAINTAINED UNDER PRESSURE BY A VALVE. BUT, THERE MAY BE ABSOLUTELY NO MEANS OF IMPOSING PRESSURE BY PUMP OR OTHER MEANS

Fig. 5.8 Typical installations of pressure vacuum breakers

(From *MANUAL OF CROSS-CONNECTION CONTROL PRACTICES AND PROCEDURES*, California Department of Health Services) delivered pressure should not be more than 100 psi (690 kPa or 7.0 kg/sq cm). Pressures in this range (35 to 100 psi, 241 to 517 kPa, or 2.8 to 7.0 kg/sq cm) are sufficient for normal use without risk or damage to water-using facilities in the distribution system or on the consumer's premises. Excessive pressures could cause such damage as well as unintentional higher water usage. Where high main pressures cannot be avoided (on transmission mains), pressure-reducing valves are normally used.

Promptly investigate low pressure complaints from consumers and make corrections where necessary. To determine the extent of a reported problem, use pressure gages or portable mechanical or battery-powered pressure recorders which can record data for a 24-hour period or longer by connecting to the consumer's system.

Pressure problems have many possible causes. A faulty pressure regulator might have a control water strainer which needs cleaning, or the regulator itself may be in need of repair. Sometimes, purposefully or otherwise, a line valve is left closed or partly closed causing loss of pressure, especially during higher flows. Low pressures can be caused by system lines being too small which will cause high velocities. High velocities occur when there is a large use of water due to unusually high consumer demands, fire-fighting, or a major leak. While these problems are out of the operator's control, they can be eased by maintaining adequate reserves in distribution storage. Although about 35 percent or more of the storage capacity should normally be reserved for fire demand and emergency use, excessive peak hour or peak day demands can still seriously drain the available storage. Storage reservoirs should never be allowed to run too low. Activating a well or an interagency connection or increasing pumping to provide more water might alleviate the situation. A potential source of an emergency water supply is older reservoirs that have been taken out of service when the physical growth of the service area has left them at too low an elevation to be useful; however, they have been kept available for emergency purposes. By slightly modifying the piping and using portable pumps, these older reservoirs can be used during emergencies.

Pressure problems can also be caused by pump failure. If automatic pump controls fail, the pumps must be operated with manual overrides during peak periods. If the pumps themselves fail or the power fails, the availability of self-powered pumps and generators is invaluable. Distribution system operators should have the basic knowledge to make prompt repairs on pumps which have failed and the necessary repair parts should be readily available. Operators should have access to emergency equipment and rental equipment with the authority to act.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

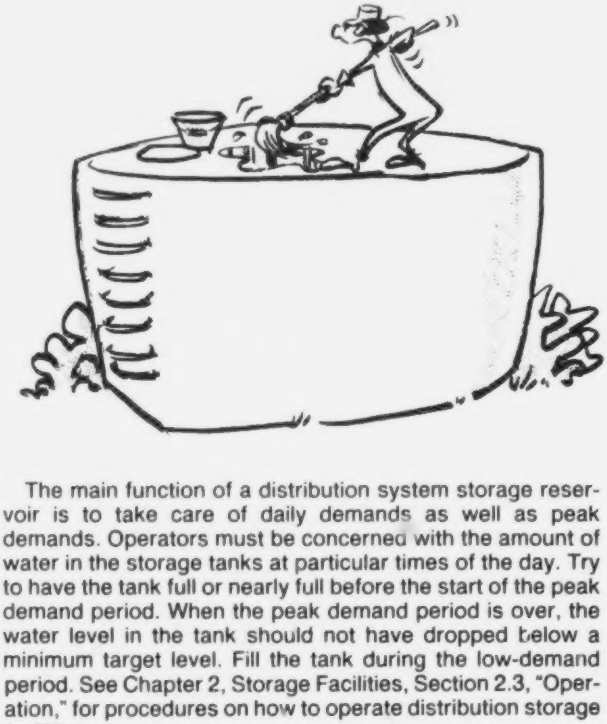
5.4A Why should a distribution system be under a continuous positive pressure at all times?

5.4B What problems may be caused by excessive distribution system pressures?

5.4C What are the possible causes of low water distribution system pressures?

5.5 DISTRIBUTION STORAGE

Surveillance of distribution storage facilities was discussed at the beginning of this chapter. Deficiencies found during surveillance should be taken care of as soon as possible. Any condition that might affect the quality of the water in the reservoir must be corrected immediately. When leaving the reservoir site either after surveillance or completion of other work, be particularly careful to leave all locks in a locked position and make sure the reservoir is completely secured.



The main function of a distribution system storage reservoir is to take care of daily demands as well as peak demands. Operators must be concerned with the amount of water in the storage tanks at particular times of the day. Try to have the tank full or nearly full before the start of the peak demand period. When the peak demand period is over, the water level in the tank should not have dropped below a minimum target level. Fill the tank during the low-demand period. See Chapter 2, Storage Facilities, Section 2.3, "Operation," for procedures on how to operate distribution storage facilities.

QUESTIONS

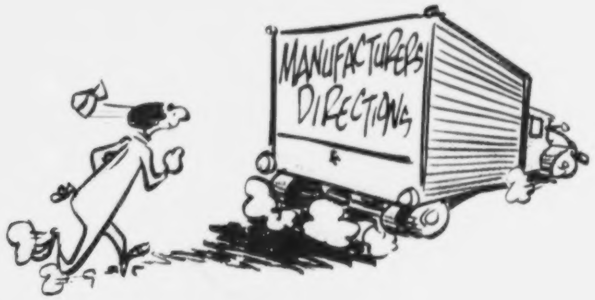
Write your answers in a notebook and then compare your answers with those on page 276.

5.5A What is the main function of a distribution system storage reservoir?

5.5B When should a distribution storage reservoir be full?

5.6 PUMPS

A comprehensive preventive maintenance program is necessary for all pump installations. Without such a program, the continued satisfactory operation of the pumps will be threatened and may result in unsatisfactory system performance. In many systems, a lengthy pump outage will severely strain the ability of the system to continue to serve sufficient water. Written detailed inspection, operation and maintenance procedures should be available at convenient locations for all operators responsible for these duties. The statement, "When all else fails, follow directions" was never more true than for pump operation. Manufacturers' directions should be closely followed.



Pumps must be firmly installed to prevent problems from operating noise levels and alignment during the life of the equipment. Alignment procedures for the pump and driver are critical. There should be no strain on the pump case from the suction and discharge piping connections.

The starting, stopping and regulation of pumping equipment can be achieved manually, automatically, or semi-automatically. There has been an increasing use of sensing and automatic control devices. The variables sensed may be water elevation, water pressure, quantity of water pumped, or any combination of the three. Long distance (remote) sensing operations may be effected through leased telephone circuits, by radio, or simply by pressure communicated through the water in the pipelines. The entire pumping function in a complex distribution system can be operated and controlled from a single point or control station or from multiple points.

As pump operating conditions vary widely, it is impossible to provide a preventive maintenance schedule that would apply to all systems. Regular inspections must be planned and followed. Inspection schedules are often based on the number of expected pump operating hours since the last inspection. A record of the inspections and of the pump maintenance performance must be kept so there is assurance the necessary scheduled procedures are being followed.

Inspection and preventive maintenance procedures will cover many types of operations. Some of the more important procedures are listed below.

1. Observe and record pump pressures and output (flow), and the pump's current (electricity) demands.
2. Make visual checks for excessive or abnormal noise, vibration, heat and odor.
3. Provide grease and oil lubrication in accordance with the manufacturer's instructions. Lubrication should never be overdone as the addition of too much grease will cause a bearing to overheat, and too much oil will result in foaming. Proper lubrication for pump bearings cannot be overemphasized. The conditions of operation will determine how often a bearing should be greased.
4. Check bearing temperatures once per month with a thermometer. If the bearings are found to be running too hot, it could be the result of too much lubricant. Every three months, check the lubricated bearings for "saponification." This is a soapy or foamy condition of the lubricant which usually results from water or other fluid infiltrating past the bearing shaft seals. If the grease appears as a white foamy substance, flush the bearings with kerosene or solvent, clean thoroughly, and repack with the type of lubricant recommended by the manufacturer.
5. Listen for any bearing noise. Usually a ball bearing will give audible notice of impending failure. This early warning will give you time to plan a shutdown for maintenance.
6. Tighten the packing glands if they are leaking excessively. The tightening should be sufficient to permit only a small amount of leakage, but not result in an increase in packing-follower heating. Packing glands should never be tightened to the point where there is no leakage since this will cause undue packing wear and even a scored shaft or sleeve. Check the leakage rate daily. When the packing wears or is compressed so that the gland cannot be tightened farther, install a new set of rings. While mechanical seals require higher initial cost than packing, long-term costs may be lower.
7. Inspect the pump *PRIMING*[8] system. A priming system must be used to prevent the pump from running dry if the pump operates with a *SUCTION LIFT.*[9] To protect against loss of prime, check valves or foot valves on the intake or suction piping of a pump are a necessity. Use only clean water for the priming. To facilitate priming, ejectors or vacuum pumps are also available. As the pumps are also prone to airbinding, they are usually provided with manual or automatic vent valves on top of the pump casing. One type of priming pump installation is shown in Figure 5.9.
8. Routinely operate internal combustion-driven pumps and generators on standby for 15 minutes once per week. Also check any automatic pump controls. If they fail during an emergency, the pumps must be operated with manual overrides.
9. Check pump alignment periodically to guard against premature bearing and coupling wear. Alignment should be checked when the pump is cold, and again when a unit has run long enough for it to reach the proper operating temperature. Alignment on new installations can change considerably in a short period of time. Daily checks should be made until a stable operation has been established.

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[8] *Prime. The action of filling a pump casing with water to remove air. Most pumps must be primed before startup or they will not pump any water.*

[9] *Suction Lift. The NEGATIVE pressure [in feet (meters) of water or inches (centimeters) of mercury vacuum] on the suction side of the pump. The pressure can be measured from the centerline of the pump DOWN TO (lift) the elevation of the hydraulic grade line on the suction side of the pump.*

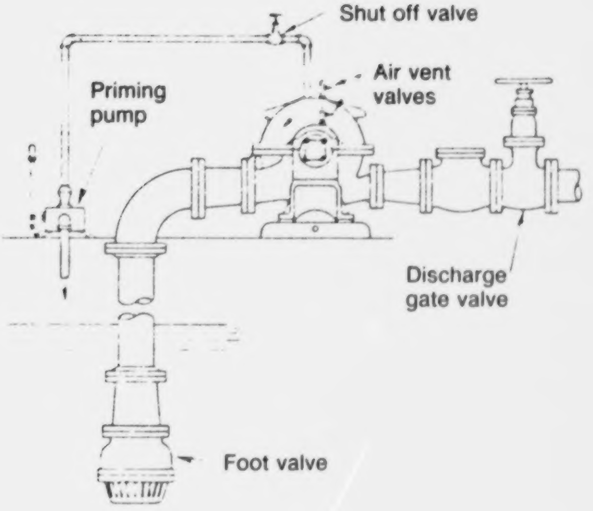

Fig. 5.9 Pump priming installation

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

As pumps and controls are generally powered by electrical energy, the operator should have some working knowledge of electrical circuits and circuit testing instruments if effective maintenance is to be provided. Although the operator is usually not expected to be an expert in this field, an understanding of the basics of electricity is important if for no other reason than to learn how to avoid electrical shock.

An electric motor failure can have serious consequences. The principal causes of such a failure are overheating caused by overloading, a locked rotor, rapid cycling, loss of cooling due to clogged or impeded ventilation, or low water level in a submersible pump casing. When overheating occurs, power is usually shut off by protective devices installed in motor circuits. Become familiar with these devices and learn where and how to reset them after finding the problem, if any, which caused the tripping of the circuit.

For an excellent summary of pump troubleshooting procedures, see Chapter 2, Table 2.2, Centrifugal Pump Troubleshooting Chart, page 44. For additional information on pump maintenance, see Chapter 18, Section 18.2, "Mechanical Equipment," in *WATER TREATMENT PLANT OPERATION*, Volume 11, in this series of manuals.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.6A Why are pump alignment procedures for the pump and driver critical?

5.6B List the important pump inspection and preventive maintenance procedures.

5.6C What types of checks should be performed on bearings?

5.6D When should new pump packing rings be installed?

End of Lesson 1 of 4 Lessons
on
DISTRIBUTION SYSTEM
OPERATION and MAINTENANCE

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 1 of 4 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers in your notebook before continuing.

1. How would you prepare emergency operating procedures for a water distribution system?
2. Why should water distribution systems have a system surveillance program.?
3. How could you determine the condition (smoothness) of the inside of a pipe?
4. What normal security measures should be taken to prevent vandalism?
5. Under what conditions should a water supply facility be immediately taken out of service?
6. Why are the States encouraged to implement the National Secondary Drinking Water Regulations?
7. What items should be included in a water supplier's cross-connection control program?
8. What problems can an operator expect from open distribution storage reservoirs?
9. How frequently should a storage tank be cleaned?
10. Why is a comprehensive preventive maintenance program essential?

CHAPTER 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 2 of 4 Lessons)

5.7 WATER MAINS AND APPURTENANCES

5.70 Pipe

5.700 Pipe Maintenance

Pipe maintenance is performed to prevent leakage, maintain or restore the pipe's carrying capacity, maintain proper water quality conditions in the pipe, and prolong the effective life of the pipe. A pipe's useful life can be greatly extended if it is properly maintained and rehabilitated. The type of maintenance carried out includes repairing leaks and breaks, flushing, cleaning, disinfecting and relining.

Pipes deteriorate on the inside because of water corrosion and erosion and on the outside because of corrosion from aggressive soil moisture. Even under the best of conditions, pipe can be weakened and damaged with time. All types of metal, concrete, and asbestos-cement pipe are subject to some deterioration. This deterioration may be revealed as a loss of water carrying capacity, leaks or degradation of water quality. Loss of water carrying capacity can result from corrosion, pitting, tuberculation, deposition of sediment and slime growth.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.70A What types of pipe maintenance are performed by distribution system operators?

5.70B What causes pipe deterioration?

5.701 Locating Leaks

Leak detection programs are an effective means for some water utilities to reduce operating and maintenance costs. If a leak detection crew can reduce the flow of leaks and produce cost savings greater than the cost of maintaining the field crew, then the leak detection program is economically justified. Leak detection programs can also be justified in terms of the early detection and repair of leaks while they are small, before serious failure occurs with resulting property damage, crew overtime, delays of other projects and similar problems. Also a water shortage may require an effective leak detection program.

Leaks may originate from any weakened joint or fitting connection or from a damaged or corroded part of the pipe. Leaks are undesirable not only because they waste water, but because they can undermine pavements and other structures. Another undesirable effect of leaks is that the leak soaks the ground surrounding the pipe and in the event that pressure is lost in the pipe, the water, combined now with dirt and other contaminants, may backflow into the pipe. The total amount of leakage in a distribution system is affected by a number of factors. Improper pipe installation (bedding, backfill, misalignment) can result not only in weakened joint and fitting connections, but also in damage to the pipe itself and to any corrosion-protection measures that have been provided. The pipe's durability, strength and corrosion resistance will vary with the type of pipe material used. Protection against corrosion is certainly one of the more important maintenance factors which will minimize leakage. The older the pipe, the more time there has been for corrosion to act and for the pipe system to be weakened, especially at joints and fittings. The longer the pipe system, the more "opportunity" (joints) for leaks to occur. Aggressive water and soil will accelerate corrosion in susceptible pipe. Finally, systems with higher pressures produce more leakage.

The process of locating a leak is often not easy and sometimes becomes a troublesome and frustrating experience. Methods used to locate leaks include direct observation, use of sounding rods, listening devices, and data from a waste control study.

The simplest method is to search for and locate wet spots which might indicate the presence of a leak. Sometimes these are reported by the system's customers. However, even if a damp spot is found, it does not necessarily mean that the leak can be easily found. The leak may be located directly below the damp area or it may be 50 yards (46 m) or more away. Often the leak is someplace other than where it would be expected because water will follow the path of least resistance to the ground surface.

After the general location of the leak has been determined, a probe may be used to find it exactly. This probe is a sharp-pointed metal rod that is thrust into the ground and then pulled up for inspection. If the rod is moist or muddy, the line of the leak is being followed. *BE CAREFUL YOU DON'T PROBE INTO AN ELECTRICAL CABLE.*

Listening devices are made up of sound-intensifying equipment that is used in a systematic fashion to locate leaks. The simplest listening device is a steel bar held against the pipe or valve. The device is moved in the direction of increasing sound until the leak is found. Patented leak detectors use audiophones to pick up the sound of escaping water. Some types of test rods can be driven into the ground and held against the pipe or held against aboveground hydrants and valves. Different types of leak detection equipment are shown in Figures 5.10, 5.11 and 5.12.

A water audit is a thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system. This allows the water utility to select and implement programs to reduce water and revenue losses. Such examinations must be performed annually to update the results of an earlier audit.

Benefits resulting from a water audit can be significant, including:

1. *Reduced Water Losses* - Conducting a leak detection project will identify and locate system leakage. Upon repair of the leaks, water savings will result. Savings are also realized in reduced power costs to deliver water and reduced chemicals to treat water;
2. *Financial Improvement* - A water audit and leak detection program can increase revenues from customers who have been undercharged, lower costs of wholesale supplies, and reduce treatment and pumping costs;
3. *Increased Knowledge of the Distribution System* - The added familiarity of the distribution system gained during a water audit and leak detection project helps a utility to respond more quickly to such emergencies as main breaks;
4. *More Efficient Use of Existing Supplies* - Reducing water losses will help stretch existing supplies to meet increased needs. This could help defer the construction of new water facilities, such as a new well, reservoir, or treatment plant;

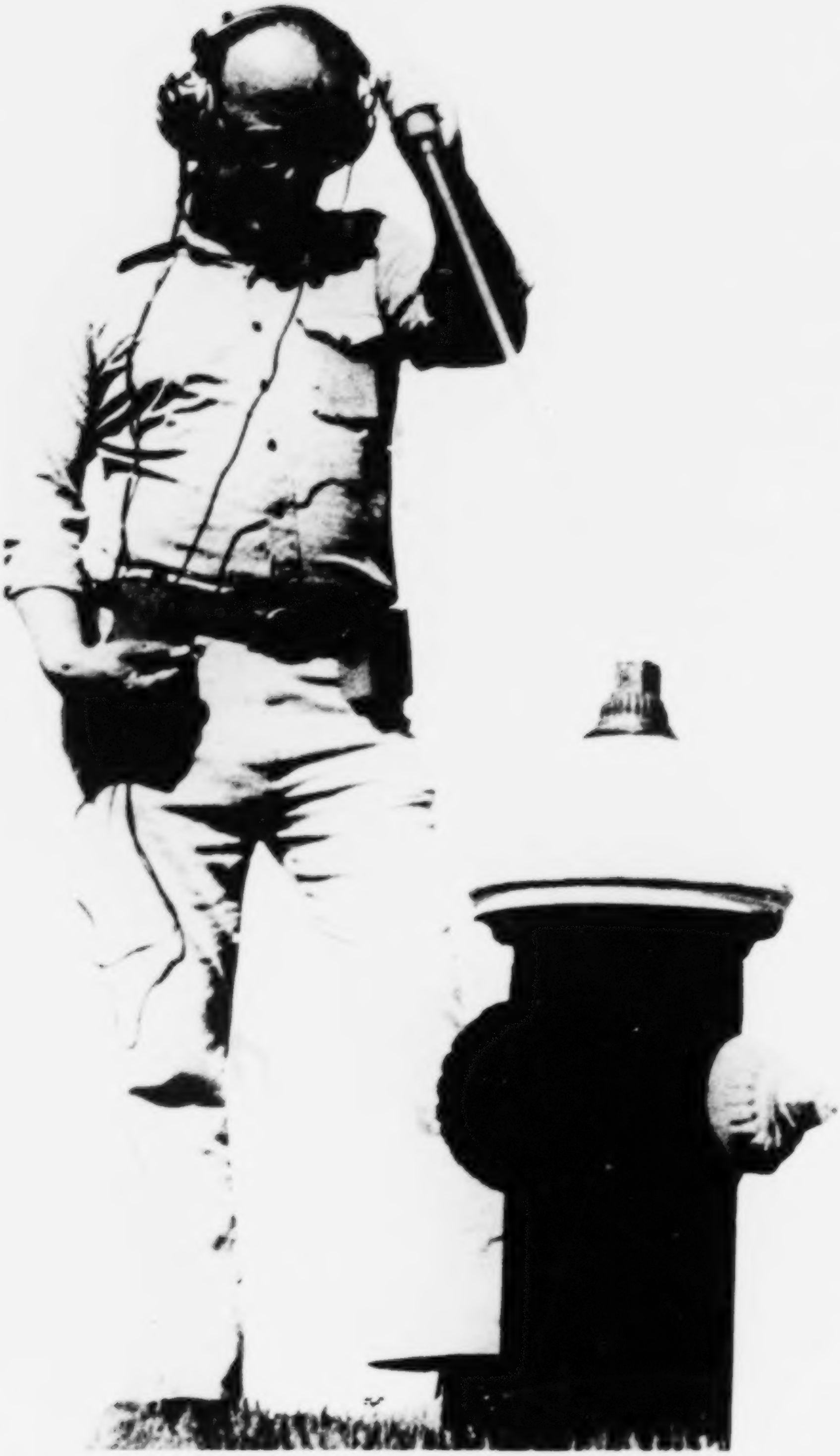

Fig. 5.10 Leak detection instrument

(Permission of Heath Consultants, Inc.)

Fig. 5.11 Leak detection
(Permission of Heath Consultants, Inc.)

5. *Reduced Property Damage* - Improved maintenance of a water distribution system can reduce the likelihood of property damage and better safeguard public health and safety;
6. *Improved Public Relations* - The public appreciates seeing that its water systems are being maintained. Field teams carrying out water audit and leak detection tasks and doing repair and maintenance work make a favorable impression.
7. *Reduce Legal Liability* - Conducting a water audit and leak detection project provides better information for protection against expensive lawsuits.

Waste control or water audit studies are usually conducted when no specific reason can be found for a significant water loss in the system. Routine comparisons of water production and use should be made to determine the amount of unaccounted for or "lost" water. The amount of unaccounted for water that is acceptable depends largely on the conditions in each system. In some systems, there is concern when the loss exceeds 10 percent of the water produced while in other systems there is little concern until 20 percent of the water produced cannot be accounted for. The amount of unaccounted for water is affected by leaks, pressures, efficiency of meter maintenance, and the attention given to leakage reduction and unauthorized uses of water. Leakage has already been discussed. Higher pressures not only result in more leakage, but increase the under-registration of meters. Meters also tend to under-register as they get older and if they are not being properly maintained. Utilities that pay attention to finding and eliminating hidden losses of their supply will naturally have a more efficient and cost-effective operation.

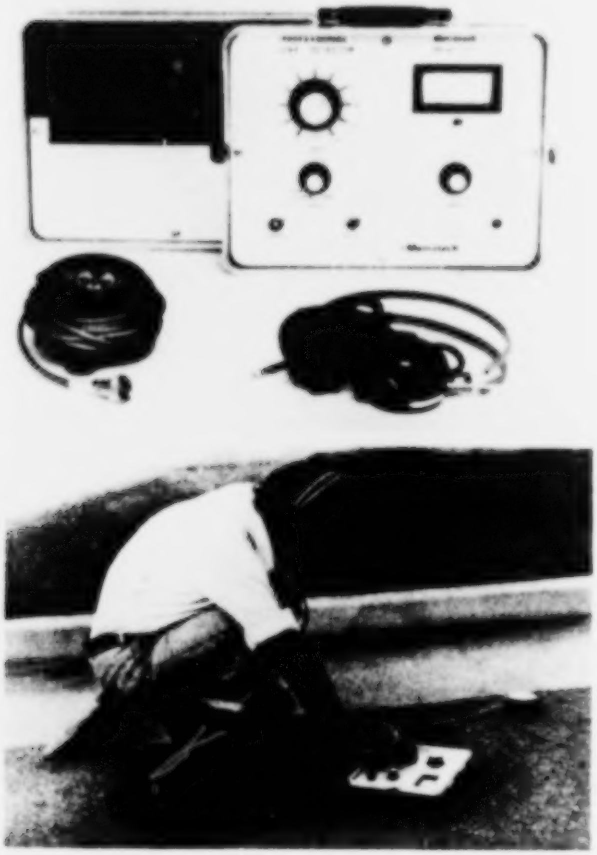

Fig. 5.12 Leak detector
(Permission of Metrotech)

Waste control studies basically involve flow measurements beginning at the source of supply and working out into the system. The system's source and master meters are checked out first. Then separate areas ("districts") are isolated via appropriate valve manipulations. All the water to the isolated district is made to pass through a single pipe where the flow is measured with a meter. Usually, there is an average of about 18 miles (29 km) of mains per district, but this could vary from 4 to 46 miles (6 to 75 km), depending on the situation. If the flow through the pipe is found to be greater than normal, the isolated district is divided into smaller districts to narrow in on the source of the abnormal use, leaks, or wastage. Measurements of water consumption are made in the late evening hours because they are more likely to indicate leakage, waste or abnormal use of water without the complications presented by normal daytime use. Those areas where unexplained high consumption rates are found are further investigated in detail by visual and sounding methods. Surface areas can be observed for wet spots or depressions, and valves, hydrants and services can be sounded for typical audible vibrations produced by water escaping from defects in the underground piping.

The most convenient flow measurement device used in studies of this type is the pitotmeter which is a reversible (water velocity) pitot tube that can be inserted into a main through a one-inch (25 mm) corporation cock (Figure 8.13). The differential pressure (D) caused by the velocity of the water flowing past the openings to the tubes is calibrated to the average velocity of the water flowing in the main. Recording devices can be used with it to record continuous flow rates over time periods of 12, 24, or 48 hours. This type of meter has a field accuracy of ± 2 percent and can measure flows over a wide range from a few thousand gallons per day to over 200 MGD (750 m*L*/day).[10]

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.70C Where can leaks originate?

5.70D How are probes used to locate leaks?

5.70E Why are waste control studies (water audits) conducted?

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[10] *750 megaliters per day or 750 million liters per day.*

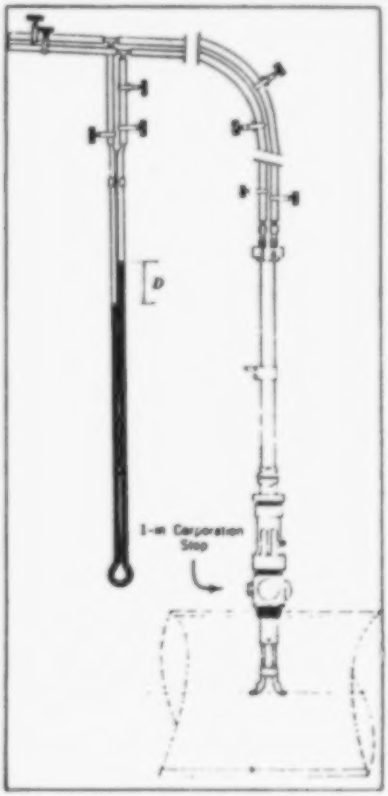

Fig. 5.13 Modified pitot meter

(Reprinted from AWWA *WATER DISTRIBUTION TRAINING COURSE*, by permission. Copyright 1962, the American Water Works Association)

5.702 Locating Pipes

Ideally, all pipe in a water system would be in standardized, easy to find locations and maps would be available showing precisely where the installation was made. Unfortunately, this ideal situation rarely exists. Other measures must often be used to locate the pipes while searching for a leak, when a new connection is to be made or if an excavation must be made in the area to locate or install other nearby facilities. Even when good records are available, an accurate determination of the underground facilities should be made in the field. Numerous devices have been developed to expedite finding buried pipe. One of these devices is shown in Figure 5.14. Electronic pipe finders consist basically of a portable radio-direction-finder receiver. The transmitter induces an electromagnetic field into any buried metallic object within its range. As the receiver is carried across a pipe location, the induced electromagnetic field is detected and produces an audible tone in the earphones used and a deflection on a visual indicating instrument. Both the position and depth of the buried pipe can usually be determined. Another device used is a stainless steel tipped shaft which is pushed into the ground to locate the pipe. For future location of non-metallic pipe, a metallic tracer tape (wire) which is detectable by electronic finders is put on top of the pipe before it is covered.

5.703 Repairing Leaks and Pulled Services

After the leak has been located, route traffic around the work area and take any other necessary safety precautions *BEFORE* starting excavation. Also try to locate other underground utilities *BEFORE* starting any excavation. Many phone books list an "Underground Service Alert" or "One-Call" phone number which should be called *BEFORE* digging or drilling underground.

A maintenance crew excavates and uncovers the leaky pipe. Sometimes a dewatering pump is also needed to drain the hole before it is possible to work around the pipe. If the main must be isolated before the repairs are made, notify all affected consumers in advance and give them an estimated length of time that the main will be out of service. Leaks at joints or splits or breaks may have to be repaired. Shoring may be required depending on depth of pipe and soil conditions. A good slogan to remember is, *"WHEN IN DOUBT, SHORE IT."*[11] The simplest repair is accomplished by using repair clamps (Figure 5.15). These devices are short, cylindrical pieces usually made of one piece of pipe or in two halves and bolted together or otherwise fastened around a pipe, covering a break, or making a joint between two pipes. For long splits or other defects, clamps up to 18 inches (450 mm) long with rubber or lead gaskets are available. Repair of cracks and breaks in steel pipe is often done by welding. Joint leaks in caulked bell and spigot joints can be stopped by recaulking, by clamps (Figure 5.15), or the entire joint may be removed and replaced. If the main was taken out of service and drained during the repair job, flush and disinfect the main and test a sample for coliforms before placing the main back in service.

Occasionally a contractor digging another utility trench will hit a service line and pull the corporation cock out of the main line. To repair a break of this type, follow the procedures in this section and also in Section 5.74, "Main Breaks." Be sure to notify all consumers who will be without water how long they can expect to be without water. Some agencies notify the consumers before any valves are closed to isolate the break while others close the valves first. If extensive damage is occurring (erosion, wash outs and flooding) as a result of the break, close the valves as soon as possible.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.70F Why does the location of a buried pipe sometimes have to be determined?

5.70G How can buried non-metallic pipes be located?

5.70H How can a leak in the wall of a pipe be repaired?

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[11] *See Chapter 3, Distribution System Facilities, Section 3.653, "Excavation and Shoring," for details.*

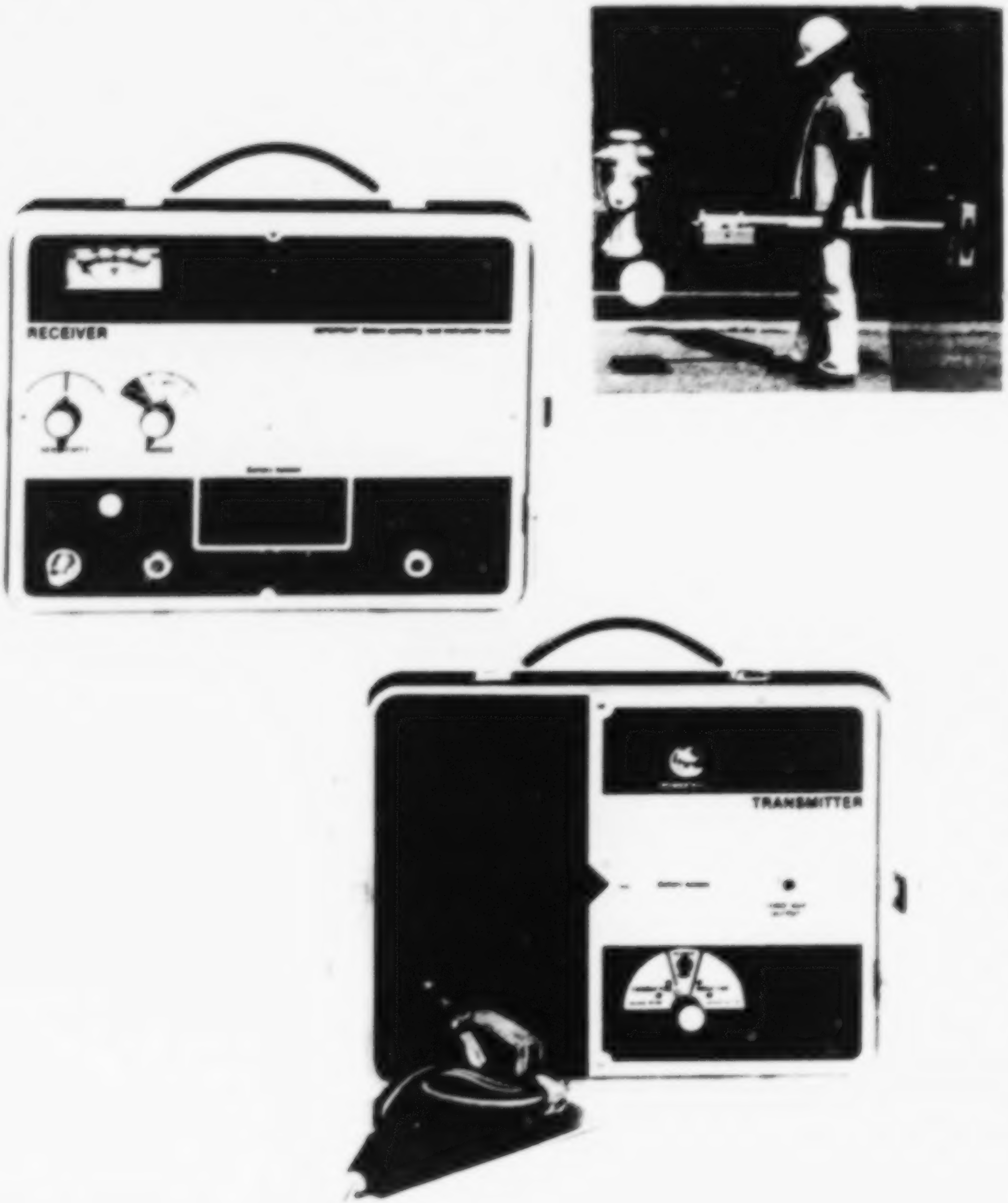
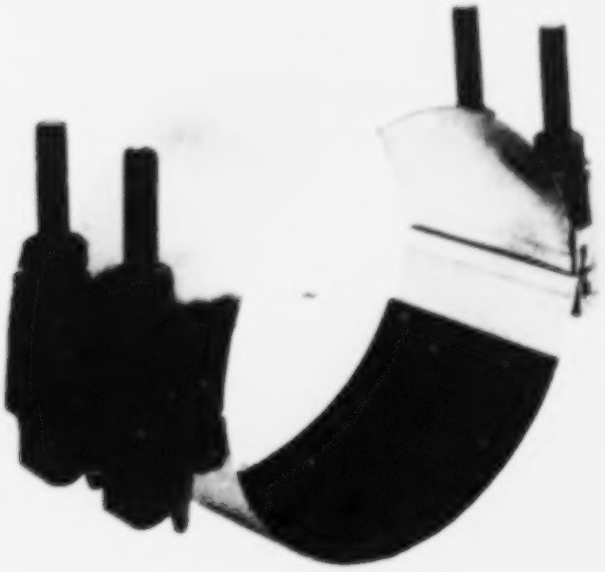
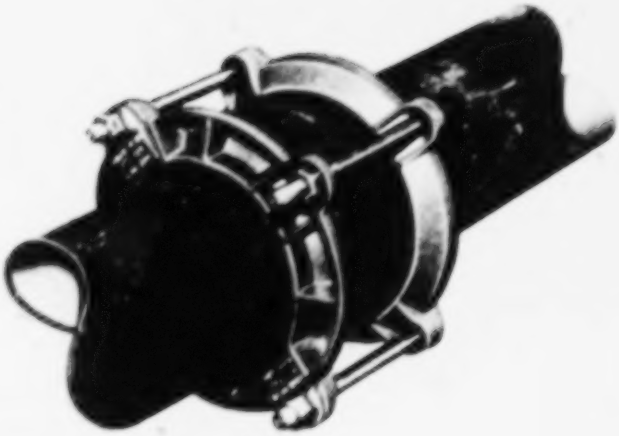

RECEIVER
TRANSMITTER

Fig. 5.14 Devices for locating buried pipe
(Permission of Metrotech)



Pipe clamp for repairing pin holes, cracks, bruises, fractures, holes and other damage in any type of pipe



Bell joint clamp for repairing or preventing leaks in cast iron bell and spigot caulked or rubber ring joints

Fig 5.15 Leak repair clamps

(Courtesy of Rockwell International Corporation, Municipal & Utility Division)

5.704 Making Pipe and Service Connections

Every water utility agency should have a policy regarding the installation of services and setting of meters to insure the consumer of an effective installation and to avoid problems in the future. Perhaps the most satisfactory policy is for the agency to install all services and meters. If the workload is too great for agency crews, all contractors and plumbers should be notified of required procedures and fittings. Work done in new subdivisions is usually performed by contractors. All installations should be inspected and tested for leaks by the agency *BEFORE* the installation is covered with backfill.

Connections from existing pipe are often made to a new main or a new service pipe. Making service connections, from a street main to a home, is one of the most frequently performed jobs in a water system. Ideally, when new mains are installed, the connections for the service pipe are made prior to pressurizing the main.

The most common method used in making a connection is "wet tapping" where the connection is made with the main under water pressure. A corporation stop is directly inserted into the main (ductile iron and PVC thick wall pipe) using a tapping machine. Although it is called a tapping machine, this device allows three operations to be performed on a main under pressure and should more properly be referred to as a drilling, tapping, and inserting machine.

To insert a tap into a main under pressure, the first step is to excavate down to and around the main. Install shoring if necessary. Clean the main. Install saddle and tapping equipment. Be sure the saddle and equipment are tight.

A combined drill and tap is used to first drill a hole into the pipe (Figure 5.16a). Then, a tap is inserted into the main to thread the hole (Figure 5.16b). Next, still using the tapping machine, the threaded inlet of a corporation stop is threaded into the hole (Figure 5.16c). Wet taps are frequently made with a clamp and corporation stop. Rarely is a corporation stop screwed into a main under pressure. Finally, the service line is connected to the corporation stop fitting to be activated when the corporation stop is turned on.

Large service connections are usually made using wet tapping with the water mains under pressure. This is much more convenient for both the water utility and the customer. No customer is out of water, and the job can be done at the convenience of the water utility. Wet tapping also eliminates complaints of dirty water which frequently result when shutting down a section of main. In addition, wet tapping avoids loss of considerable amounts of water.

If you do not have the capabilities for wet tapping, you will have to use a dry tapping machine after closing off the valves and emptying that part of the main which will be tapped. In this operation, attach a service clamp around the main and then thread the corporation stop into it (Figure 5.17).[12] With the corporation stop in an open position, attach the drilling device to the corporation stop's outlet threads and drill a hole or make a shell-cut through the wall of the main. After the main is cleaned, bolt a tapping sleeve to it. A tapping sleeve is a split sleeve or clamp in one half of which is an opening with a flange or other means of attaching a valve. Figure 5.18 is a picture of one type of tapping sleeve used. Next, attach a tapping valve (a permanent valve installation) to the sleeve outlet (Figure 5.19a). Then attach the drilling machine and adapter to the valve outlet flange (Figure 5.19b). With the tapping valve open, advance the cutter and drill a hole into the pipe; retract the cutter and close the tapping valve (Figure 5.19c). After removing the drilling machine, attach a new lateral to the valve outlet flange and activate it by opening the valve.

5.705 Special Investigations

Early detection of potential failures or deficiencies in service can be recognized and corrected in advance by making pressure, flow, hydraulic grade line and pipe *C FACTOR*[13] surveys. Pressure surveys can indicate the hydraulic efficiency of the system in meeting normal requirements. These surveys are performed by attaching a pressure gage to a hose nozzle or a hydrant or other available connection, opening the valve, and reading the pressure in the main (Figure 5.20). The best location to obtain pressure readings is the closest possible location to the main being tested. Pressure gages often receive rough handling and should be tested and recalibrated periodically to insure accurate readings. If a pressure record covering a longer period of time is desired, a recording pressure gage is used to evaluate changing conditions. Pressure readings are of special interest during periods of maximum demands.

Pressures may fall off in some parts of the system due to an increase in water use by consumers, leaks, obstructions or diminished carrying capacity in the pipes. Pressure readings can be taken at various points in the system to follow out the changes in pressure and locate the problem areas. Results of pressure tests combined with rate-of-flow (fire) information are very useful in locating the source of a pressure problem.

Use flow tests to determine the efficiency and adequacy of a distribution system in transmitting water and to measure the amount of water available from hydrants for fire fighting. This information is of particular importance during peak demand periods. Flow tests are usually made from hydrants using a pitot gage. Hydrant flow tests are made by measuring flow from one or more hydrants and at the same time noting the change in pressures at a nearby hydrant when going from no flow to full flow.

HYDRAULIC GRADIANT[14] tests are used to determine the ability of the distribution system to maintain adequate pressures throughout the system. As the purpose of these tests is to find any weaknesses in the system, they are normally run during peak periods of delivery when such weaknesses are most evident. Plotting the pressure measurements at various points in the system will give you a visual picture of the losses of head between these points as the water is distributed through the system.

Pipe interior roughness coefficient (C Factor) tests will demonstrate whether or not friction losses in the pipe are

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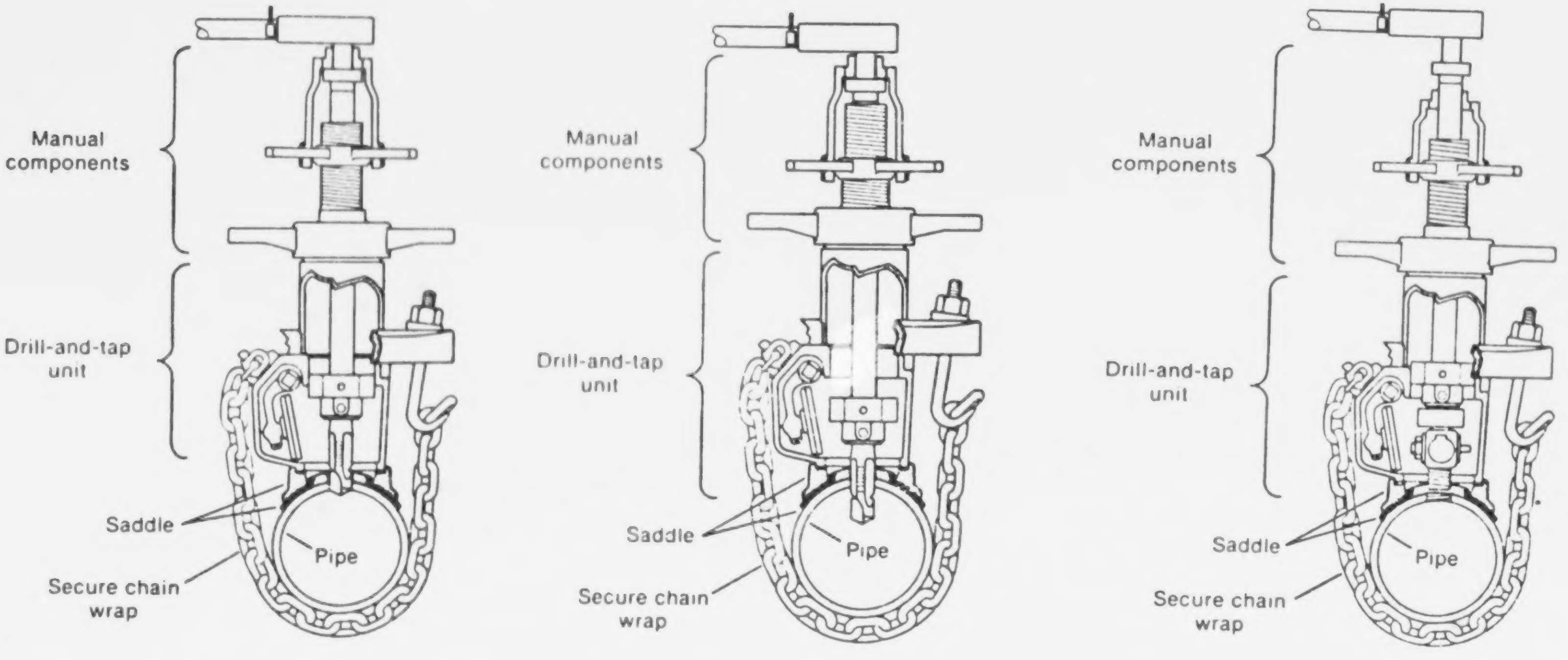
[12] *Some agencies use this type of equipment for wet tapping.*

[13] *C Factor. A factor or value used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between two pressure gages, and the friction or energy loss of the water between the gages.*

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75(\text{Diameter, ft})^{2.63}(\text{Slope})^{0.54}}$$

[14] *Hydraulic Gradient. The slope of the hydraulic gradient line. This is the slope of the water surface in an open channel, the slope of the water surface of the groundwater table, or the slope of the water pressure for pipes under pressure.*


Manual
components
Drill-and-tap
unit
Saddle
Pipe
Secure chain
wrap
Manual
components
Drill-and-tap
unit
Saddle
Pipe
Secure chain
wrap
Manual
components
Drill-and-tap
unit
Saddle
Pipe
Secure chain
wrap

a. With the combined drill-and-tap unit, first drill a hole into the main.

b. After the hole is drilled, insert the tap.

c. Again, with the drill-and-tap unit, insert the threaded inlet of a corporation cock. The service can then be activated.

Fig. 5.16 Wet tapping

(Art reproduced by permission of Mueller Company)

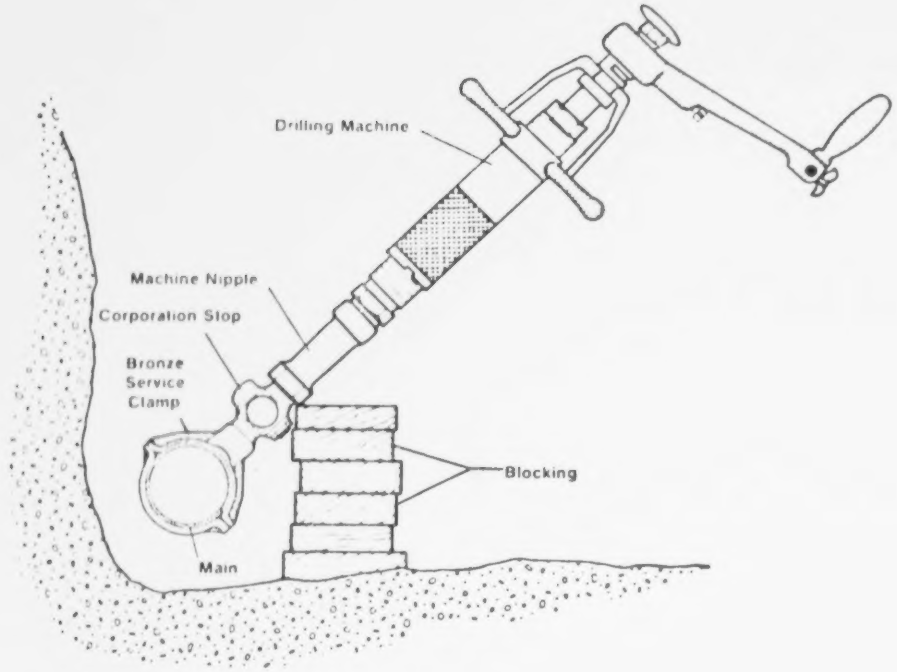

Drilling Machine
Machine Nipple
Corporation Stop
Bronze Service Clamp
Blocking
Main

Fig. 5.17 Dry tapping
(Art reproduced by permission of Mueller Company)

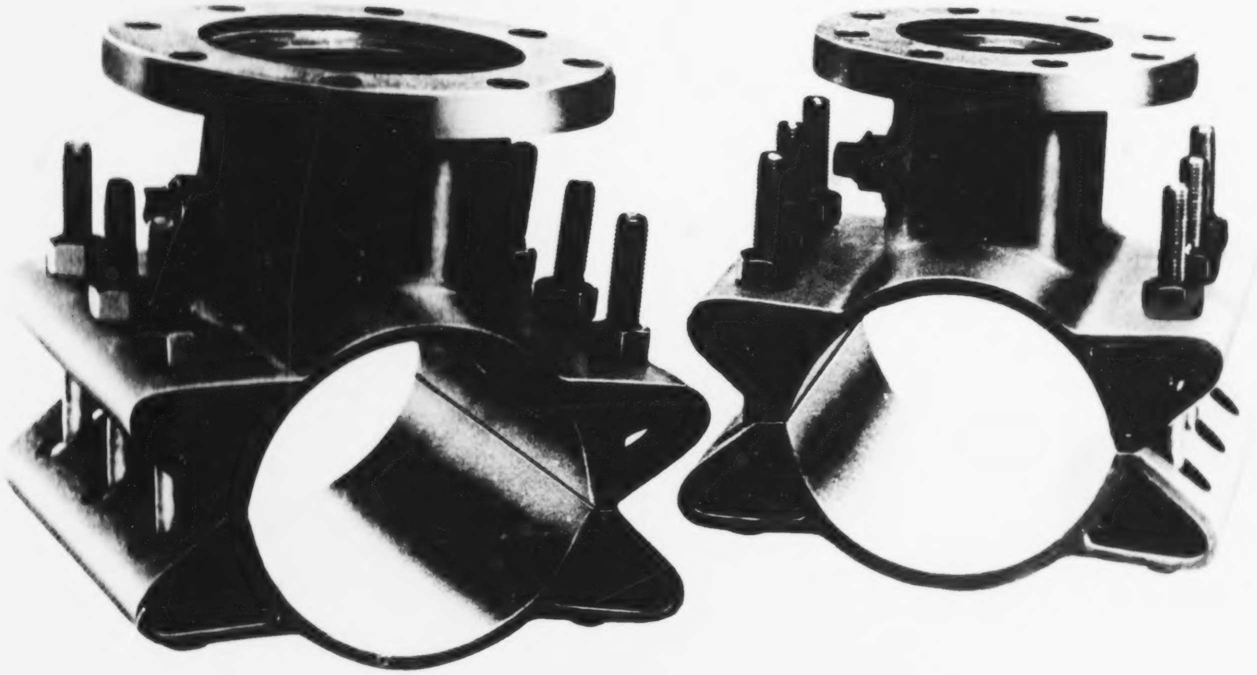
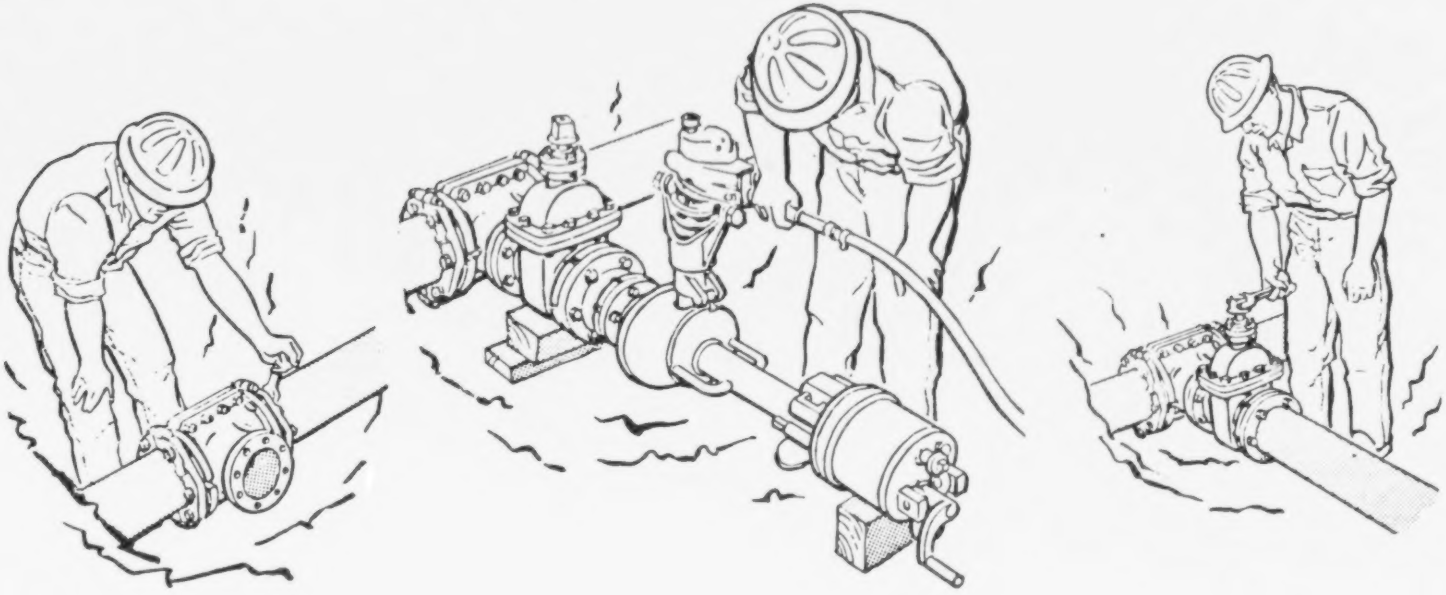


Fig. 5.18 Tapping sleeves
(Courtesy of Rockwell International Corporation, Municipal & Utility Division)



a. Clean the main and then bolt the tapping sleeve to it. Attach tapping valve to sleeve outlet.

b. Attach the drilling machine and adapter to valve outlet flange. Position support blocks. Open tapping valve, advance cutter, and drill hole inside of pipe inside the sleeve.

c. Retract cutter and then close tapping valve. Remove drilling machine and attach new line or lateral. Open tapping valve, activating new line.

Fig. 5.19 Drilling machine

(Art reproduced by permission of Mueller Company)

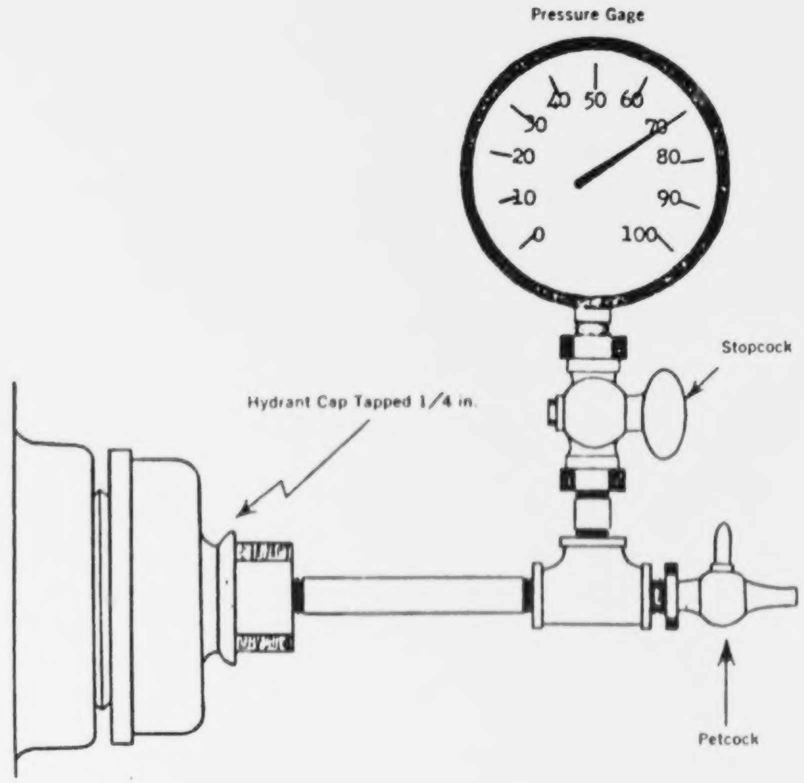


Fig. 5.20 Gage assembly for measuring hydrant pressures

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increasing and whether the ability of the pipe to transmit water is being seriously hindered. Isolate the pipe under study as much as possible and close even the service connections if you can. Using two points a known distance apart, determine the hydraulic gradient and measure the flow (normal or induced) through the pipeline. Using this data, calculate the pipe roughness coefficient (C Factor). Once the coefficient is known, head losses under other flows can be determined for the particular section of pipe. For procedures on how to calculate the C Factor, see Chapter 3, EXAMPLE 3, page 69, or the Appendix at the end of this manual, Section A.134, "Distribution System Facilities," EXAMPLE 17.

'C' FACTOR
PIPE
FACTOR
COEFF

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.70I What is wet tapping?

5.70J Why are pressure surveys of a water distribution system conducted?

5.70K How can an operator obtain a pressure record covering a long period of time at one location?

5.706 Pipe Flushing

Flushing is done to clean out distribution pipelines by removing any impurities or sediment that may be present in the pipe. Routine flushing of dead-end lines is often necessary to avoid taste and odor complaints. Many operators use flushing as a short-term solution to distribution system problems. Flushing is commonly practiced after receiving water quality complaints (red water, sand and grit, tastes and odors, cloudy (air), and something swimming), when the water in the system appears to have become contaminated, and to clean newly installed or repaired mains prior to disinfection.

Flushing may remove deposits, encrustations, sediments and other materials. Deposits which have settled out and accumulated in pipelines may result in taste, odor, and turbidity problems. Encrustations may restrict the water flow. Sand, rust and biological materials cause quality problems and are not uncommon in pipelines. The needed frequency of routine flushing can usually be determined by customer complaints and the types of material found during the flushing procedure. Flushing should not be considered as the only solution to distribution system water quality problems. The water utility should always try to prevent water quality degradation through proper design, operation and treatment.

Water mains should be flushed before consumers start complaining about poor water quality. Flushing should be conducted during periods of low water demand (spring or fall) when the weather is suitable. Prior planning and good communications will allow the flushing crew to conduct the flushing operation quickly and without confusion. Flushing crews consist of two operators. The following procedures are recommended for flushing operations.

1. Preplan an entire day's flushing using the available distribution system maps. Consider flushing at night between 9:00 pm and 5:00 am to minimize any inconvenience to customers. Night operations encounter little traffic, but traffic must be made aware of the operation if it will be affected by the flushing. Warning devices include lights, traffic cones, barricades and flagmen.
2. Determine where sections of mains are to be flushed at one time, the valves to be used, and the order in which the pipelines will be flushed.
3. Start at or near a source of supply and work outward into the distribution system.
4. Assure that an adequate amount of flushing water is available at sufficiently high pressures. A *MINIMUM* flushing velocity of 2.5 ft/sec (5 ft/sec preferred) (0.75 and 1.50 m/sec) should be used. Do not flush a large main supplied by a single smaller one if a choice is possible.
5. Prior to flushing the mains, notify all customers who will be affected of the dates and times of the flushing through billing, newspapers, and local radio and TV announcements. Explain the intent and objective of the flushing program. Notify individuals who might be on dialysis machines and also hospitals, restaurants, laundromats, and others who might be affected while the mains are being flushed.
6. Isolate the section to be flushed from the rest of the system. Close the valves slowly to prevent water hammer.
7. Open the fire hydrant or blowoff valve slowly.
8. Direct flushing water away from traffic, pedestrians, and private lots (Figure 5.21). Avoid erosion damage to streets, lawns and yards by the use of tarpaulins and lead-off discharge devices. Try to avoid flooding which can cause traffic problems.
9. Open hydrant fully for a period long enough (5 to 10 minutes) to stir up the deposits inside the water main.
10. Assure that system pressures in nearby areas do not drop below 20 psi (138 kPa or 1.5 kg/sq cm).
11. Record all pertinent data regarding the flushing operation as well as a description of the appearance and odor of the water flushed. Figure 5.22 is a sample flushing log sheet than can also be used for a pipeline cleaning operation.
12. Collect two water samples from each flowing hydrant, one in the beginning (about 2 to 3 minutes after the hydrant as opened) and the second sample when the discolored water turns clear (just before closing the hydrant). These samples allow a check on the water quality for certain basic water quality indicators (iron, chlorine residual, turbidity) and the development of water quality trends for comparison purposes.
13. After the flushing water becomes clear, slowly close the hydrant or blowoff valves.
14. In areas where the water does not become completely clear, the operator should use judgment as to the relative color and turbidity and decide when to shut down. A water sample in a clear glass bottle will allow the operator to visually observe the color from time to time.
15. Mark closed valves on a map when they are closed and erase marks after the valves are reopened. Do this promptly and do not depend on memory.
16. After one section of pipe has been flushed, move on to the next section to be flushed and repeat the same procedures.

FORMULAS

The formulas needed to calculate a desired flow meter reading in gallons per minute (GPM) to flush a water main are the same formulas we've used before.

To calculate the cross-sectional area of a pipe when the diameter is given in inches,

$$\text{Area, sq ft} = \frac{0.785\ (\text{Diameter, in})^2}{144\ \text{sq in/sq ft}}$$

To calculate the flow in a pipe in cubic feet per second (CFS), we need to know the area in square feet and the velocity in feet per second. This is the familiar formula, Q = AV.

$$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

To convert the flow from cubic feet per second (CFS) to gallons per minute, GPM,

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48\ \text{gal/cu ft})(60\ \text{sec/min})$$

EXAMPLE 4

A 15-inch diameter water main is to be flushed at a velocity of 5 ft/sec. What should be the reading on the flow meter in gallons per minute?

Known		**Unknown**
Diameter, in	= 15 in	Flow, GPM
Velocity, ft/sec	= 5 ft/sec	

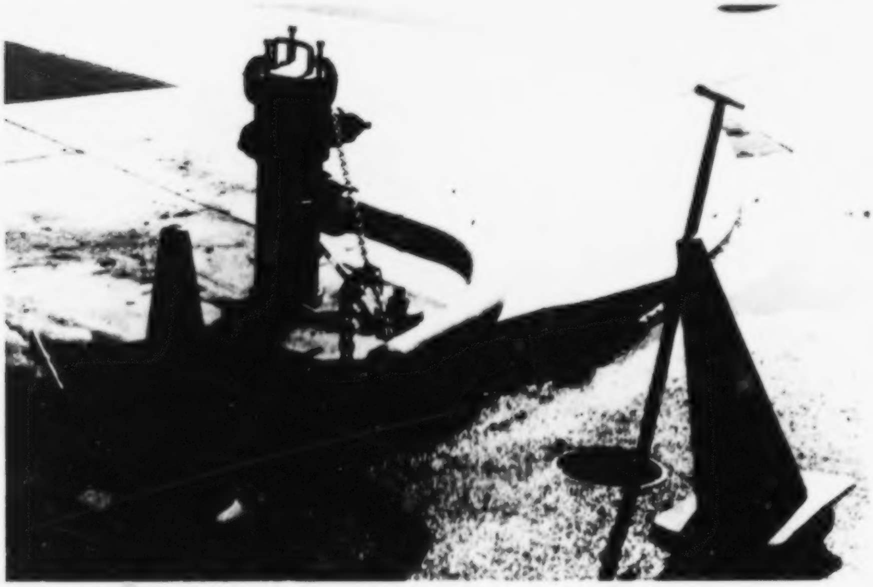
FORMULA (Q = AV)

$$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

1. Calculate the cross-sectional area of the pipe in square feet.

$$\begin{aligned}\text{Area, sq ft} &= (0.785)(\text{Diameter, ft})^2\\ &= \frac{(0.785)(15\ \text{in})^2}{144\ \text{sq in/sq ft}}\\ &= 1.23\ \text{sq ft}\end{aligned}$$

Direct flushing water away from traffic, pedestrians, underground utility vaults, and private lots.



Deflection tubes keep water and swabs from going into traffic on a busy street. Without the chain, vibration will break tube.

Fig. 5.21 Diverting flushing water

Date	Time	Location	Press. Zone	Size of Main		Swabs	P	d	Q	V	Time	Flushed Water Description
				D Dia, in	L Length, ft	# of Runs # per Run	Pitot Press., psi	Disch. Opening, in	Flush. Rate, GPM	Flush. Velocity, fps	Req'd. to Clear, min.	

Q = Flushing rate in GPM

d = Diameter of nozzle or opening in inches

P = Pitot gage pressure at nozzle or opening in psi

$Q = 26.8\, d^2 \sqrt{P}$

V = Flushing velocity in main in fps

D = Diameter of main being flushed in inches

$$V = \frac{0.409\, Q}{D^2}$$

Fig. 5.22 *Main flushing and swabbing log*

2. Determine the flow in the pipe in cubic feet per second (CFS).

Flow, CFS = (Area, sq ft)(Velocity, ft/sec)

=(1.23 sq ft)(5 ft/sec)

= 6.15 CFS

3. Calculate the flow meter reading in gallons per minute (GPM).

Flow, GPM = (Flow, cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= (6.15 cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= 2,760 GPM

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 276.

5.70L How is the frequency of routine flushing determined?

5.70M Why should valves be closed slowly during a flushing operation?

5.70N List the information that should be recorded during a flushing operation.

5.707 Pipe Cleaning (Swabs and Pigs)

Mechanical cleaning devices are often used to clean pipes if flushing does not provide relief from water quality problems or from problems in maintaining the carrying capacity. Foam swabs, pigs (Figure 5.23) and air have been successfully used in removing loose sediments and soft scales from mains. Pigs have also been used to flush new mains prior to disinfection. Scrapers or brushes may have to be used in mains with hardened scales or extensive tuberculation, and are usually used prior to relining. Of the available devices, foam swabs and pigs are the easiest and most effective to use. Pipe cleaning projects should produce improved pipe carrying capacity and a reduction of power (and cost) to pump the water.

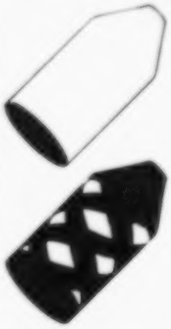
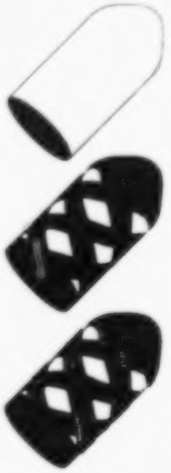
AQUA SWAB **2 LBS./CU. FT. DENSITY** Can Be Hand Launched.		**AS** (Aqua Swab) — Proving direction of flow, sealing behind undersized cleaning units, sweeping loose debris. **ACCS** (Aqua Criss-Cross Swab) — Light cleaning.
AQUA COAT **5 LBS./CU. FT. DENSITY**		**AB** (Aqua Bare) — Gauging; light cleaning **ACC** (Aqua Criss-Cross) — Cleaning **ACCWB** (Aqua Criss-Cross Wire Brush) — Scraping

Fig. 5.23 Types of swabs and pigs

(Permission of Girard Polly Pig, Inc.)

Swabs are made of polyurethane foam; both soft and hard grade forms are available. Some agencies purchase sheets of foam and cut out the desired size. They are efficient in removing loose sediments, soft scales and slimes. Use different colored swabs or some other means of identifying swabs. All swabs inserted in mains must be retrieved. Pigs are also made of polyurethane foam, but are much heavier in weight, harder, and less flexible than swabs. They are bullet-shaped and come in various grades of flexibility and roughness.

Generally, if loose sediments and soft scales in the pipe are to be removed without disturbing hardened encrustations, swabs are used. If you also want to improve the carrying capacity of the main, but not remove all the existing encrustations, then pigs should be used. However, the use of pigs is more likely to result in leaks at a later date.

A mixture of air and water can effectively clean small mains up to 4 inches (100 mm) in diameter. Air is introduced into the upstream end of the pipe from a compressor of the same type used for pneumatic tools. Spurts of water mixed with the air will remove all but the toughest scale.

The use of compressible foam swabs and pigs provides flexibility in their insertion and removal. The entry and exit points used for smaller size mains are fire hydrants, air valves, blow-offs, wyes and tees (Figure 5.23). Figures 5.24 and 5.25 show the insertion of a pig and a swab into fire hydrants. In larger mains, a section of pipe may be removed and a wye inserted in its place at the entry and exit points to allow insertion, launching and exiting of the swabs and pigs.

The routine procedures used for cleaning pipe are very similar to those used for flushing except that services to customers will have to be shut off during cleaning. Temporary services may have to be installed to some customers if there is a critical need for a continuing water supply (such as a hospital). The water used may be that from the upstream main or may be from an external pressurized water source. A swab flushing plan is shown in Figure 5.26. A typical main cleaning operation is shown in Figure 5.27. Both flushing and swabbing operations usually start near the beginning of the system and move outwards towards the ends of the system.

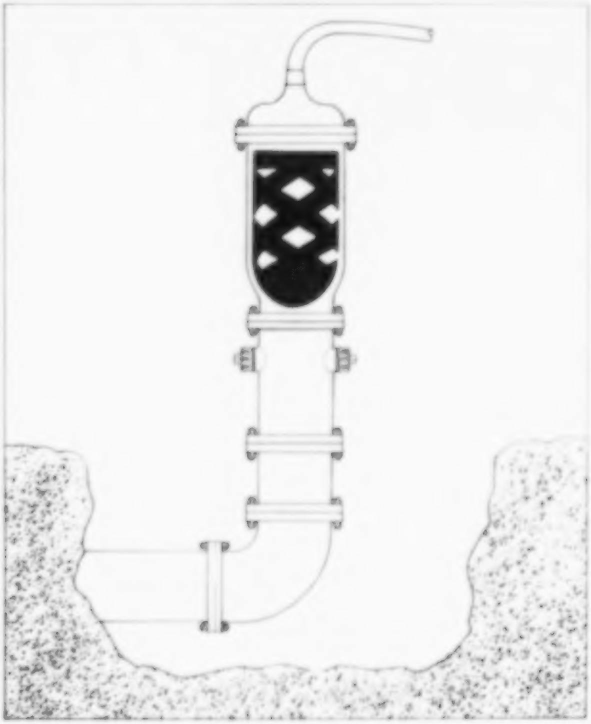


Figure 1 shows how a fire hydrant can be used to launch the Aqua Pig, by removing the internal valve assembly (including the seat) and attaching a swage reducer.

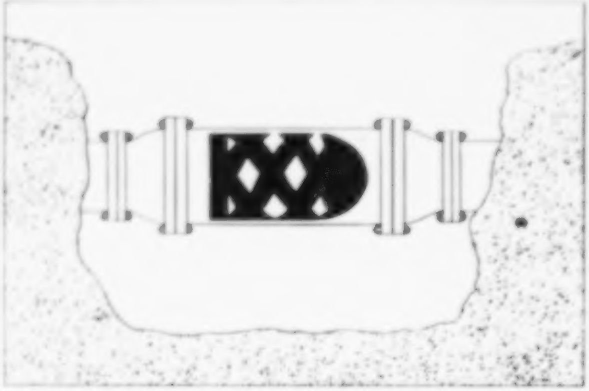


Figure 2 shows how an over-sized spool can be coupled into the line for launching.

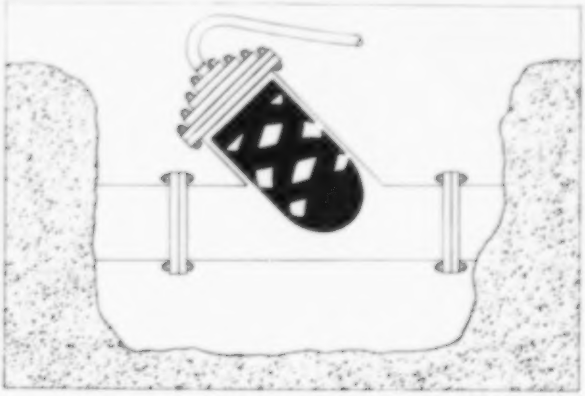


Figure 3 shows Aqua Pigs being introduced into the line through a standard "Y" section. Regular "T" sections can also be used.

Fig. 5.23 Methods of inserting and launching pigs

(Permission of Girard Polly Pig, Inc.)

Fire hydrant "pig launcher"

Insertion of pig through fire hydrant

Fig. 5.24 Insertion of pig

Insertion of foam swabs into a hydrant

If you have the screw-type hydrant in your system with the bleeders on the side that you cannot plug, you can make up a hydrant such as this with steel pipe and a reducer, moving it from job to job.

Fig. 5.25 Insertion of swab

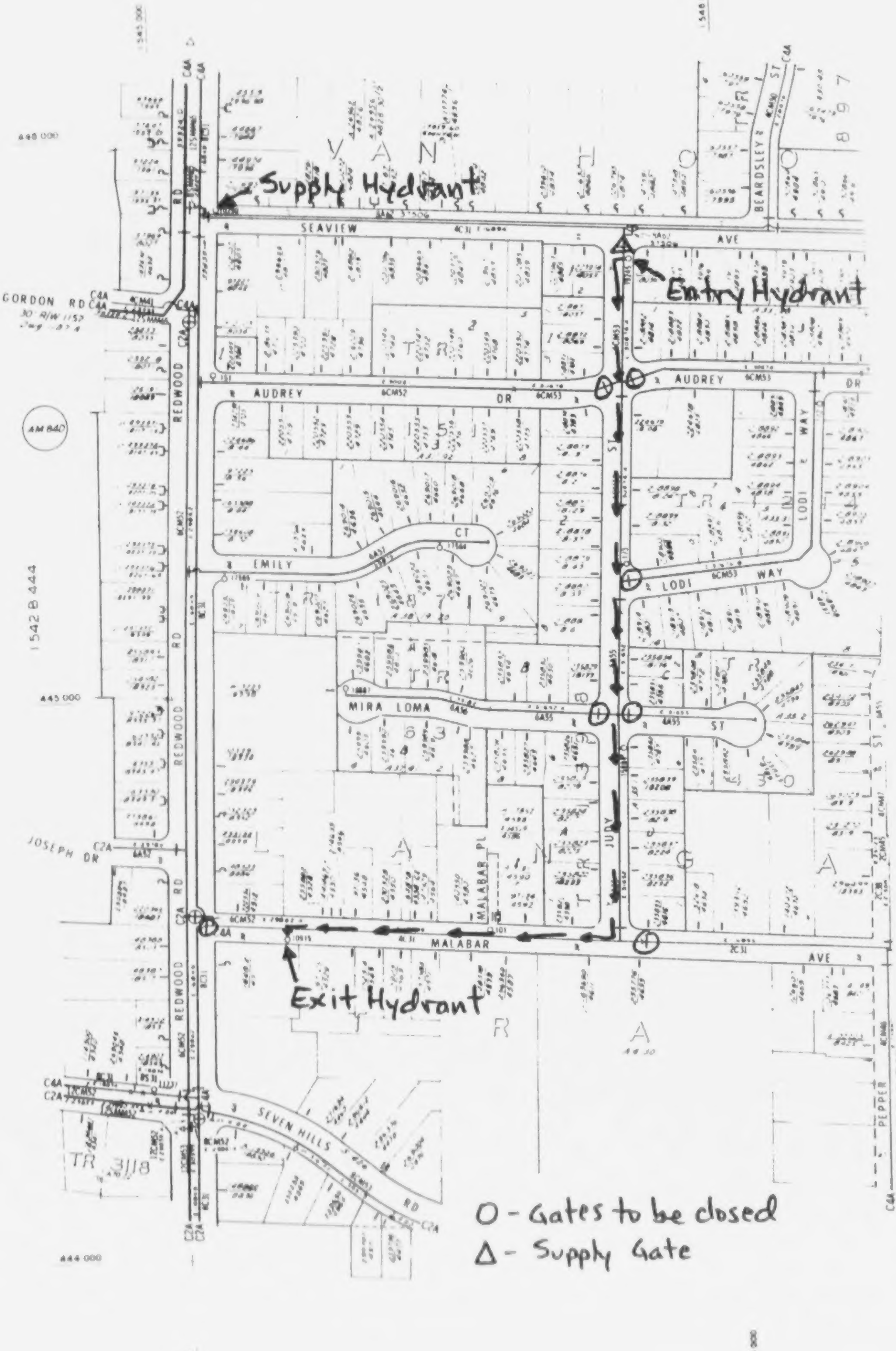
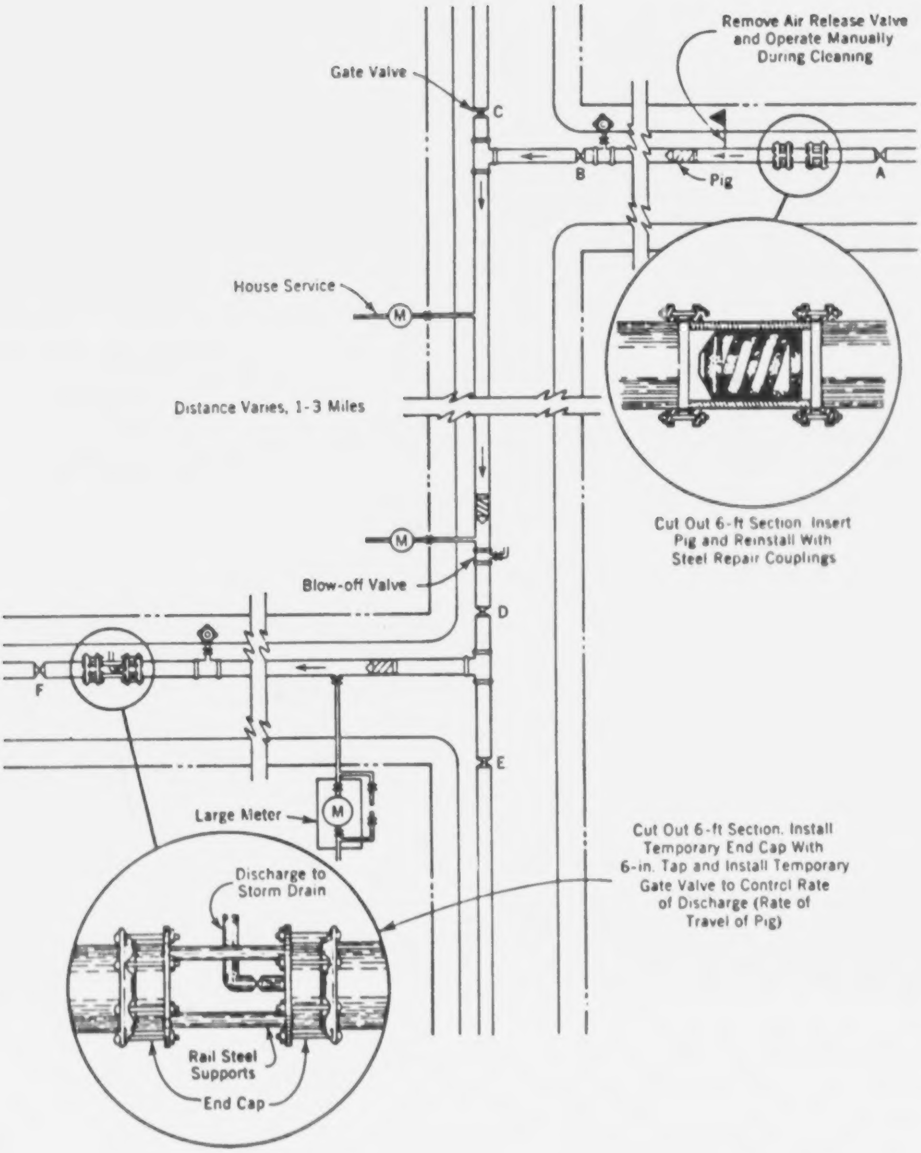

Supply Hydrant
Entry Hydrant
Exit Hydrant
O - Gates to be closed
Δ - Supply Gate
SEAVIEW
AVE
GORDON RD
30' R/W 1152
AUDREY
DR
AUDREY
DR
EMILY
CT
LODI
WAY
LODI WAY
BEARDSLEY
ST
MIRA LOMA
ST
JUDY ST
MALABAR PL
MALABAR
AVE
REDWOOD RD
REDWOOD RD
REDWOOD RD
REDWOOD RD
JOSEPH DR
SEVEN HILLS RD
PEPPER
TR 3118
AM 840
1542 B 444
448 000
445 000
444 000
1 545 000
1 548 000
0
100
200
300
400
500
600
700
800
900
1000 FEET

Fig. 5.26 Swab flushing plan


Remove Air Release Valve
and Operate Manually
During Cleaning
Gate Valve
C
B
Pig
A
House Service
M
Distance Varies, 1-3 Miles
Cut Out 6-ft Section. Insert
Pig and Reinstall With
Steel Repair Couplings
M
Blow-off Valve
D
F
E
Large Meter
M
Discharge to
Storm Drain
Rail Steel
Supports
End Cap
Cut Out 6-ft Section. Install
Temporary End Cap With
6-in. Tap and Install Temporary
Gate Valve to Control Rate
of Discharge (Rate of
Travel of Pig)

Valves A and B are closed. Cut pipe and insert pig. Open valve A and fire hydrant as needed to move pig; when pig approaches, close hydrant and valves C and D and service lines. Valve B is opened and flow at blow-off is regulated to move pig; when pig approaches blow-off, valves E and F and service lines are closed. Open valve D and regulate flow using valve on end cap. Close valve D, remove end cap and pig, flush thoroughly, and replace pipe section.

Fig. 5.27 Typical main cleaning operation

(Reprinted from JOURNAL American Water Works Association, Volume 60, Number 8 (August 1968), by permission, Copyright 1968, American Water Works Association)

First insert the swab into the section of main to be cleaned (the section is already isolated). A pressurized water source such as a nearby fire hydrant can be used to launch the swab. Also a water truck with a pump can provide the pressurized water. Open the valve at the exit.

Pass the swab through the main at a speed of 2 to 4 ft/sec (0.6 to 1.2 m/sec). Using velocities in this range, up to 4,000 feet (1,200 m) of pipe can be effectively cleaned before the swab wears down to a size smaller than the main. The entire operation may thus require 10 to 20 swabs. Typically, 2 to 3 runs are made using 4 to 5 swabs in each run. Continue the cleaning until the water behind the swabs emerging at the exit clears up within one minute. All swabs inserted into and ejected from the main must be accounted for. Figure 8.28 shows swabs being flushed from an exit hydrant.

Before starting any cleaning job, determine how to dispose of or remove the water and deposits discharged from the cleaned water main. If the water is discharged onto a street or the ground, be sure that the drainage is proper and adequate. When the water flows down a street, sand bags or a screened barrier may be used to catch the solids yet allow the water to flow down a storm drain.

The procedures to follow for cleaning a water main using pigs or swabs are as follows:

1. Isolate the line to be cleaned. Be sure that those customers requiring temporary services have enough water.
2. Be sure that all valves in the section to be cleaned are fully opened.
3. Turn on the water and verify the direction of flow.
4. Run a full-sized bare swab through the main to prove the direction of flow.
5. Run a bare squeegee unit through the main. Measure the diameter of the unit upon exiting and introduce a crisscross type unit into the main that will just fit the "true" opening. Run a full-sized bare swab behind the crisscross unit to assure a tight seal. Continue this process until a unit is discharged from the main in reusable condition.
6. Increase the size of the crisscross pigs in one-inch increments until the units that measure the same as the pipe inside diameter are being used. For pipes with a buildup of hard scale, such as carbonates, crisscross wire pigs can be used on the final pass.
7. Run a full-sized bare swab to sweep out any loose debris.

To obtain the best possible cleaning results, be sure to:

1. Flush thoroughly after each pig run;
2. Avoid applying more than two wire-brush pigs on the final pass (this prevents over cleaning);
3. Launch the pigs from fire hydrants for mains of 8 inches (200 mm) or smaller, or from concentric reducers, pipe couplings, spools, eccentric reducers, in-line launchers, or by hand; and
4. Have an operator with experience in proper main cleaning procedures help you the first time you attempt to clean a main. This is good practice to avoid stuck, lost or damaged pigs or swabs

After the cleaning operation is completed, flush and disinfect (chlorinate) the main. When the main is reactivated, flush service lines and remove any temporary services.

Portions of the material in this section were reproduced from *DISTRIBUTION MAIN FLUSHING AND CLEANING*, published by the California-Nevada Section of the American Water Works Association.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.70O Foam swabs are efficient in removing what types of materials from water mains?

5.70P Where would you insert foam swabs and pigs into a small water main to be cleaned?

5.70Q What is the recommended speed range for a swab cleaning a water main?

5.70R What should be done, before use, after a water main is cleaned with a swab?

5.708 Cement-Mortar Lining[15]

Nearly all new metal mains are protected by cement lining; however, this has not always been the case. Many operators still have to operate and maintain a considerable distance of unlined pipe. As time goes by, the condition of those water mains susceptible to corrosion or tuberculation becomes progressively worse. Cement-mortar lining of metal water mains in place has proven to be very valuable where:

1. The pipe carrying capacity has been seriously decreased because of tuberculation,
2. Corrosion products are released into the water in unacceptable amounts, and
3. Abnormal leakage through poor joints or holes in the pipe wall exist.

Water mains of all pipe diameters over four inches (100 mm) have been successfully relined, but greater cost effectiveness is to be expected in relining the larger pipes [18 inches (450 mm) or larger]. Lining of pipe just after it has been cleaned is often recommended. Cleaning alone is frequently found to be only a temporary solution as tuberculations and corrosion tend to recur at a faster rate after cleaning.

If metal water mains are corroded, cement-mortar lining may be used to protect the pipe and improve the carrying capacity of the water main. Usually transmission mains larger than 18 inches (450 mm) are lined. The first step is to inspect the mains for external corrosion. If the mains are badly corroded on the outside, they will need to be replaced. Lining the inside will not solve the problem of preventing eventual collapse of the main.

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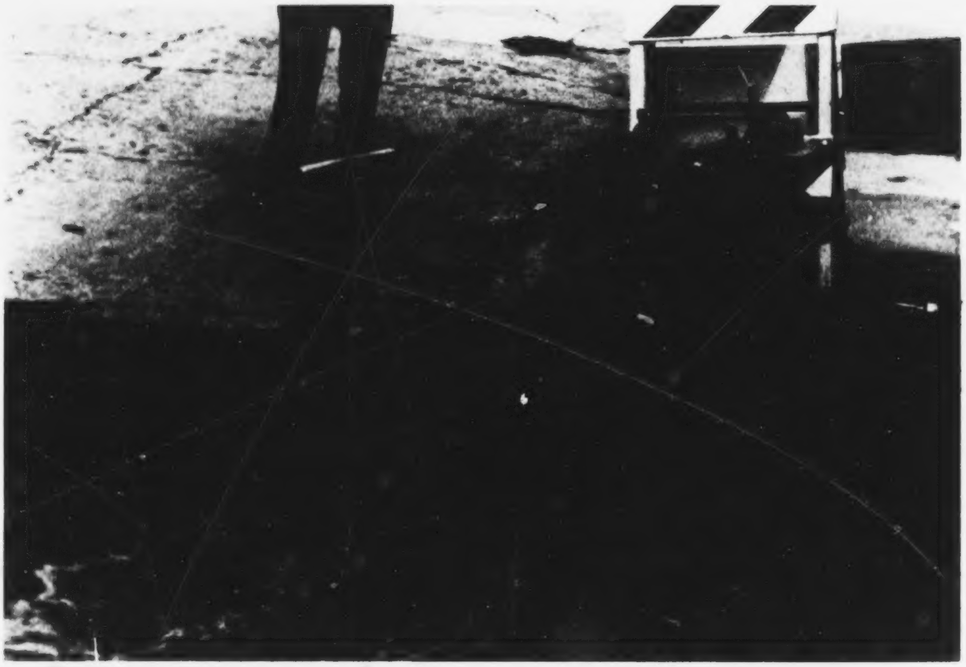
[15] *For additional information see AWWA STANDARD FOR CEMENT-MORTAR LINING OF WATER PIPELINES — 4 INCHES AND LARGER — IN PLACE, C602-83, Order No. 43602. Available from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Price to members, $7.00; nonmembers; $8.50. Other standards include C104/A21.4-85, CEMENT-MORTAR LINING FOR DUCTILE-IRON AND GRAY-IRON PIPE AND FITTINGS FOR WATER and C205-85, CEMENT-MORTAR PROTECTIVE LINING AND COATING FOR STEEL WATER PIPE — 4 INCHES AND LARGER — SHOP APPLIED.*



Dirty water flushed from main just prior to the exit of the foam swabs

Foam swabs after flushed from fire hydrant

Fig. 5.28 Foam swabs leaving system

If inspection indicates that external corrosion is not a problem, the next step is to inspect the inside of the main to determine if internal corrosion is a problem. Operators should personally inspect the inside of the main by the use of a TV camera, by crawling through the main or by being pulled through on a sled. Look for any dips in the main such as where the main had to go under a sewer or other obstruction. Dips may cause problems for the contractor's cleaning and lining equipment. If the main is corroded, then the procedures outlined in the remainder of this section should be followed to cement line the main, test it and return the main to service.

Plan to do the lining job during the time of the year when demands for water are low and the weather is suitable. Determine which sections of the main will be lined. The sections usually run from valve to valve and are around 500 to 600 feet (140 to 180 m) long. Locate the holes where the lining equipment will be inserted into and removed from the main on both sides of a valve.

Shut off each section of the main and determine if anyone is out of water. Make provisions to provide water to all consumers while the main is out of service during the lining project. New mains may have to be installed or special temporary, above-ground lines may have to be provided (Figure 5.29-1). While each section is isolated, look for any leaking valves. Sometimes old valve seats will be tuberculated and won't shut tight. These valves will have to be repaired or replaced before the lining job is started to prevent leakage from damaging the mortar before it is cured. Once everyone is assured of an adequate supply of water, the actual lining of the main can get started. This work is usually performed by an outside contractor because lining requires special equipment and specially trained personnel.

A five or six-foot (1.5 or 2 m) section of the top of the main is removed at each end of a section for the insertion and removal of the lining equipment (Figure 5.29-4). Pump or drain dry the section of the main to be lined. Inspect the main and look for any dips that must be drained. A scraper (Figure 5.29-5) is pulled through the main to remove the scale, tubercules and any old tar or other lining. Do not attempt to run a scraper past a valve because the valve seats could be badly damaged. Next an oversized squeegee is pulled through the main to clean out all remaining debris and water (Figure 5.29-6). Inspect the main to be sure it is clean. Any "live tar" (tar firmly sticking to the main) may be allowed to remain and can be covered with the mortar lining.

Insert the cement-mortar lining equipment into the main. The mortar is pumped into a header (Figure 5.29-7, 8 and 9) which applies the mortar to the side of the pipe. The mortar is sprayed by the "centrifugal method," from a rapidly rotating "head," onto the wall of the pipe as the machine carrying the spray equipment travels through the pipe. The slower the equipment moves, the thicker the lining. A troweling cone follows the mortar applicator and trowels the mortar smooth. Figure 5.30 shows a cement-mortar lining process for both smaller and larger diameter pipe.

At specified intervals some contractors will skip (not line) a short section. If there is a problem with the mortar mix, the mortar could fall off the pipe and ruin all the new lining in the entire section. This is a difficult mess to clean up. By skipping short sections, the length of failure can be confined and thus reduce the size of the clean up job and length of section which must be redone.

After a section has been lined, close the section tight and allow the mortar to cure. After 24 hours of curing, inspect the entire section. The skipped sections should be hand lined with mortar at this time. Also all valves, tees, reducers and wyes should be hand lined. Replace the five or six-foot (1.5 or 1.8 m) section which was cut out at each end of the section. A six-inch (150 mm) hand hole is cut on the top of each of these short sections. Use this hole to hand line the section. Finally the six-inch (150 mm) hand hole is lined, reinserted and sealed in place.

Pressure test the section of the main that was lined to be sure there are no leaks. Disinfect the new section by following the procedures for disinfecting mains as outlined in Section 5.8, "Field Disinfection."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.70S Why are water mains lined with cement?

5.70T Why must metal water mains be inspected on the outside before considering cement-mortar lining?

5.70U How are the insides of water mains inspected before a lining job?

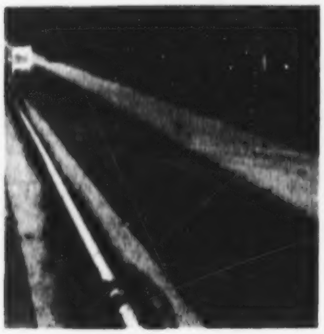
5.709 Thawing by Don Thomas

Frozen pipe can be a very serious problem in frigid climates. Difficulties are usually experienced with service lines rather than water mains because the service lines have less ground cover over them and are smaller. Also, since there is little or no flow through service lines at night, they are more likely to freeze unless water in the lines is kept moving and wasted. If a metallic pipe is frozen, electrical thawing is a quick and relatively inexpensive method to start the water flowing again. However, electric thawing can cause property damage to household electrical wiring and appliances even when done by trained and experienced operators. Operators must realize that electrical thawing can be dangerous not only to the property where the thawing equipment is located, but to other houses on the block and sometimes to houses farther away. Fires have been caused in some communities almost two blocks from the location of the equipment. For this reason many communities have codes which prohibit the use of electric thawing equipment. Due to this problem, hot water thawing is the preferred method, although it is considerably slower. These methods are explained in the following paragraphs.

A. Electrical Thawing of Frozen Water Services

1. Obtain information from the utility office responsible for thawing.

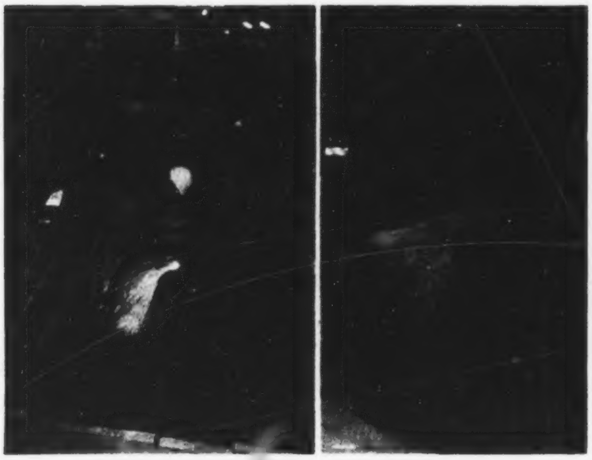
   The operator will receive a priority list of lines to be thawed from the Thawing Supervisor. The operator



1 Bypass lines are installed to provide water service to residents and businesses during rehabilitation process.

2 Small excavations are sufficient for access to the pipeline. Spacing between openings varies according to job conditions.

3 Shoring of trench prior to work on pipeline.



4-4A Six-foot (1.8 m) steel nipple is removed by cutting torch to provide access to interior of pipeline. This section is cleaned and lined separately, later reinstalled.

5 Tuberculation and scale are removed from the pipe by steel scraper blades drawn through pipeline by winch before cement-mortar lining operations begin.

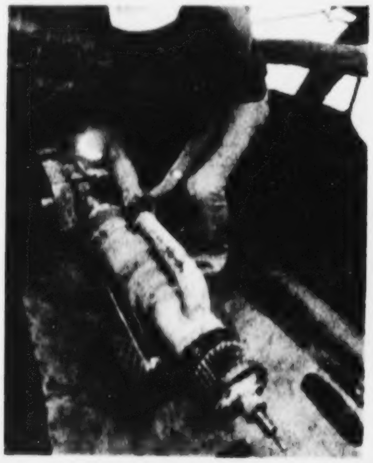
6 Emerging at end of run, squeegee assembly removes water and debris freed by steel scrapers.

Fig. 5.29 Photos showing the steps in the cement-mortar lining process

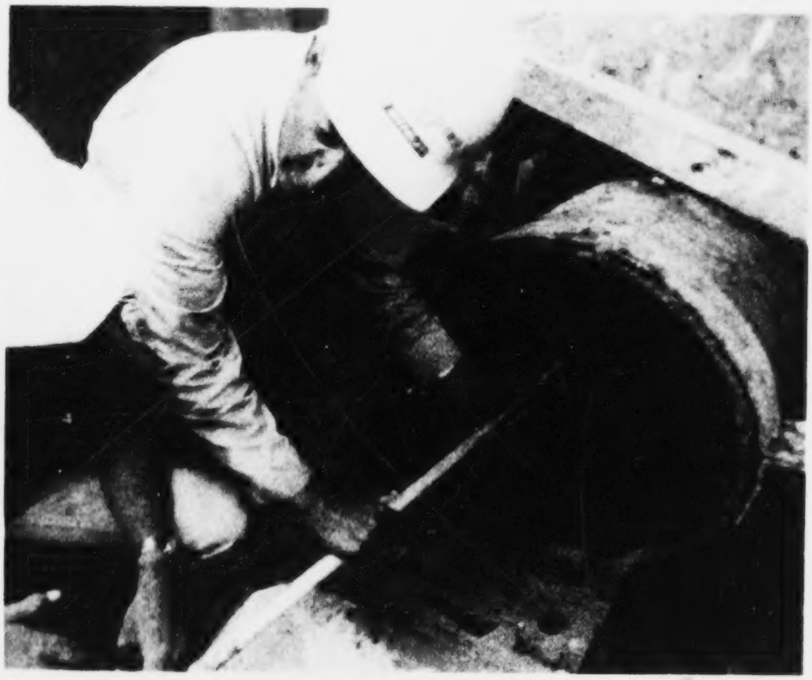
(Permission of Ameron)

7-7A Cement mortar is mixed and pumped through hose to Spunline equipment in trench

9 Trowel assembly follows Spunline unit providing a smooth surface finish



8 Attaching cement-mortar carrying hose to Spunline equipment. Spinning centrifugal head of unit in foreground sprays cement mortar on inside wall as unit travels through pipe

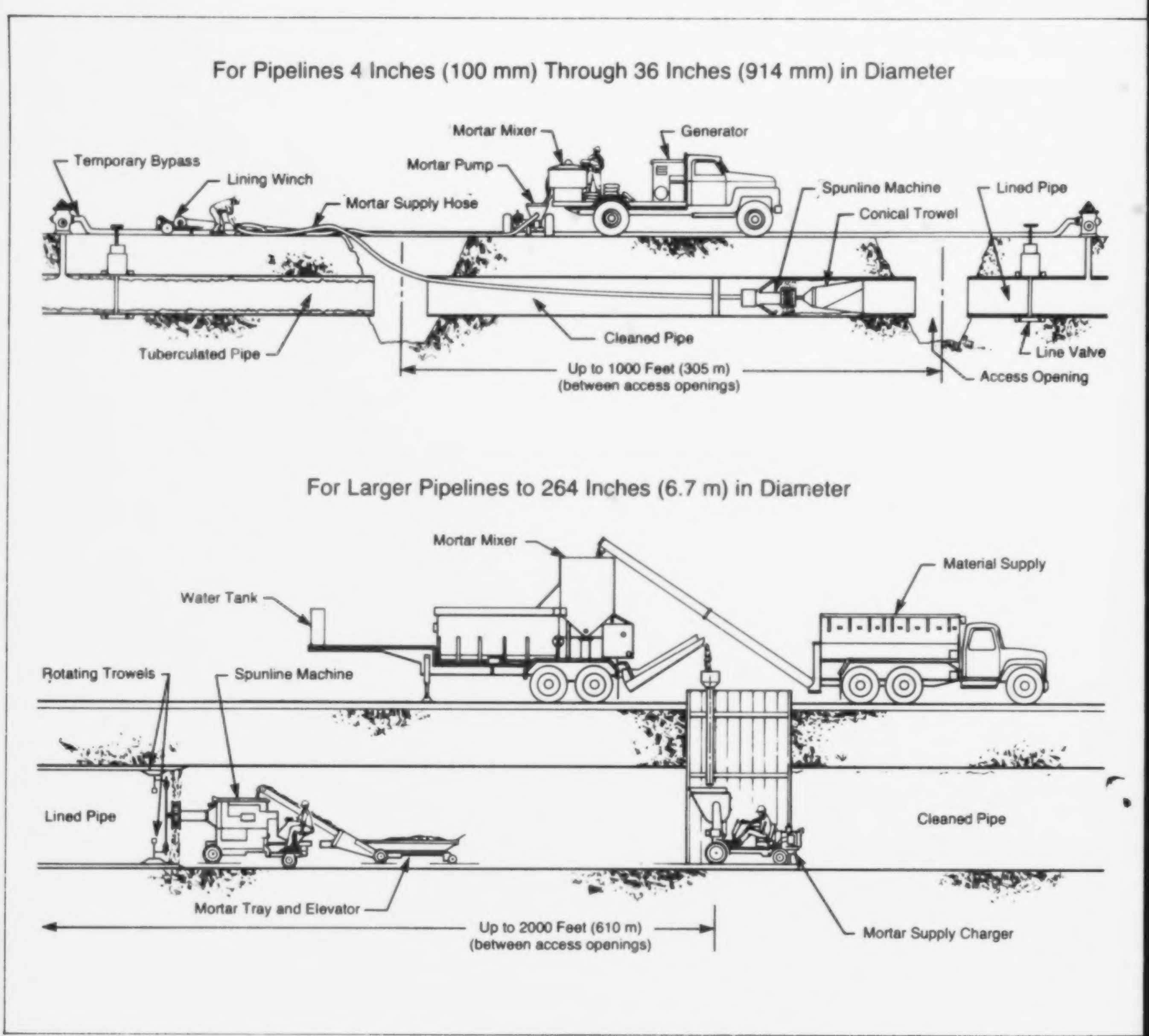


10 Inspection of pipe after cement-mortar lining has been completed

11 Typical pipe lining street scene. Minimum access requirements permit unhampered traffic flow

Fig. 5.29 Photos showing the steps in the cement-mortar lining process (continued)

(Permission of Ameron)


For Pipelines 4 Inches (100 mm) Through 36 Inches (914 mm) in Diameter

Mortar Mixer
Generator
Temporary Bypass
Mortar Pump
Lining Winch
Mortar Supply Hose
Spunline Machine
Lined Pipe
Conical Trowel
Cleaned Pipe
Tuberculated Pipe
Line Valve
Up to 1000 Feet (305 m)
(between access openings)
Access Opening

For Larger Pipelines to 264 Inches (6.7 m) in Diameter

Mortar Mixer
Material Supply
Water Tank
Rotating Trowels
Spunline Machine
Lined Pipe
Cleaned Pipe
Mortar Tray and Elevator
Up to 2000 Feet (610 m)
(between access openings)
Mortar Supply Charger

Fig. 5.30 Drawings showing cement-mortar lining process
(Permission of Ameron)

will then check the thawing card records (service cards) as to service shutoff measurements and ground wire locations, if any. These should be on or attached to existing service cards. Also, the operator should check to see if service is in a cathodically protected area; this would mean the service is isolated from the water main.

2. Locate section of frozen pipe.

   Upon arriving at given address, determine whether the service is frozen on private property or on utility's side. After locating service valve, try to operate to a half on/half off position. Listen on service to determine if there is water flowing from main to service valve. If water is flowing, you should hear water flowing out of service valve drain hole. *NOTE:* Some service valves have no drain holes, but you still have to check. There is no way of determining whether there is a drain hole or not.

3. Remove electrical grounds and disconnect lines (Figure 5.31).

   Remove any electrical grounds that are connected to the pipe in that building. Depending on the situation, you may have to remove the electrical grounds in adjacent buildings and may even have to remove the water meter. Use the services of a Journeyman Electrician for any electrical work. Also disconnect any jump wiring across the neutral wire at main fusebox. You should have power shut off to the houses beside or across the street or lane if you are going to connect thawing cables to the services there. Break the service above the stop and waste, and remove water meter and disconnect the meter by-pass, if any. These steps are taken in an attempt to eliminate all physical connections between the line to be thawed, the household piping and the electrical system.

4. Connect cable to line.

   Clean the service pipe at the point where the thawing power is to be connected (use wire brush or emery cloth). A poor electrical connection may cause arcing which could cut holes through the pipe. Arcing also wastes energy and slows the thawing process. If you can't make connections between houses, then a connection through a service valve or a pre-installed ground wire will have to be made. (Wherever possible avoid using service valves as they may be permanently damaged.) Where there is difficulty in getting connections, contact your Thawing Supervisor.

5. Use of thawing equipment.

   As a matter of safety, double check all electrical thawing equipment connections, then turn on source of electricity for thawing. Check the current and voltage in the two thawing cables. The current ammeter will indicate whether a good or a poor electrical connection has been made. This will also indicate if you are lossing current. 600 AMPS at 12 VOLTS is recommended. Once a good electrical connection has been made, the equipment doing the thawing should be watched closely until water begins to flow.

6. Turn off thawing equipment.

   When a reasonable flow of water has been obtained, the thawing equipment can be turned off and the water flow will finish thawing the line.

7. Reconnect ground wires and service lines.

   Reconnect all disconnected wires and water lines and water meters. To prevent refreezing of the thawed line, have consumer let the water run until the danger of freezing has passed. If consumer is on meter, notify meter department of present meter reading so consumer is charged flat rate for duration of potential freeze up. The consumer is issued a directive as to when to discontinue running water.

8. Complete paper work.

   Complete frozen service sheet including the address and the name of the party to whom the thawing service will be charged (Figure 5.32). The consumer should be charged when service is frozen on private property. The utility is responsible when service is frozen on utility property. Turn in paperwork to Thawing Supervisor as soon as possible.

Figure 5.33 is a copy of a letter describing "Utility policy" to customers.

B. Thawing Frozen Service Lines with a Hot Water Thawing Unit (Figure 5.34)

1. Obtain address.

   Obtain address from Thawing Supervisor. Check service card as to location of service shutoff. Check section book as to location of main and main valves.

2. Locate service curb stop.

   Locate service shutoff. Make sure shutoff is operable. Leave shutoff in open position with service key on valve rod during thawing operation.

3. Turn off stop and waste and connect to service line.

   Close stop and waste (at water meter, if any) to prevent water from draining from house or building piping.

4. Install control head.

   Install control head on to service line. Make a tight joint with a compression fitting. Some fitting variations may be required depending upon size and type of service line.

5. Insert probe.

   Feed free end of probe tubing through gland on control head (lubricate gland to assist free feeding).

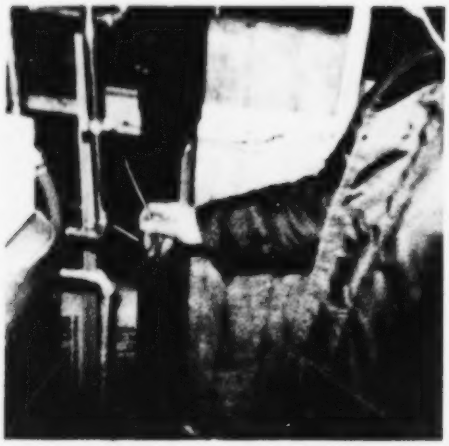
6. Connect by-pass hose.

   Connect by-pass hose to side outlet of head and anchor firmly to sink, floor drain or reservoir, such as a pail or any large container. A garbage can could be used.

7. Fill reservoir with hot water.

   Fill thawing unit reservoir (pail) with hot water (140°F, 60°C). Hot water can be obtained from hot water tank or if no water is available, go to house next door.

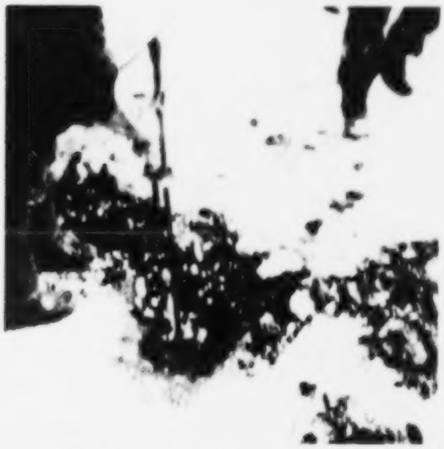
8. Feed in probe tube.



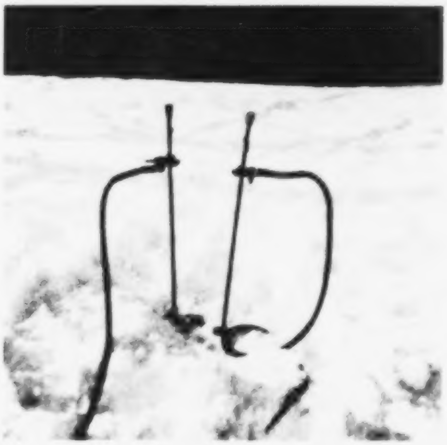
STEP #3 — Ground wire removed from service line.

STEP #3 — Service line disconnected above stop and waste

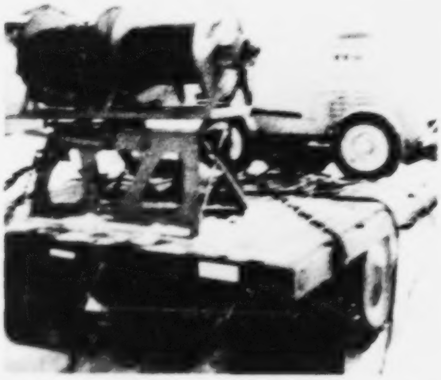
STEP #4 — Thawing cable clamped onto service key on service rod.



STEP #4 — Thawing cable clamped onto service key on ground wire cable at main cock.

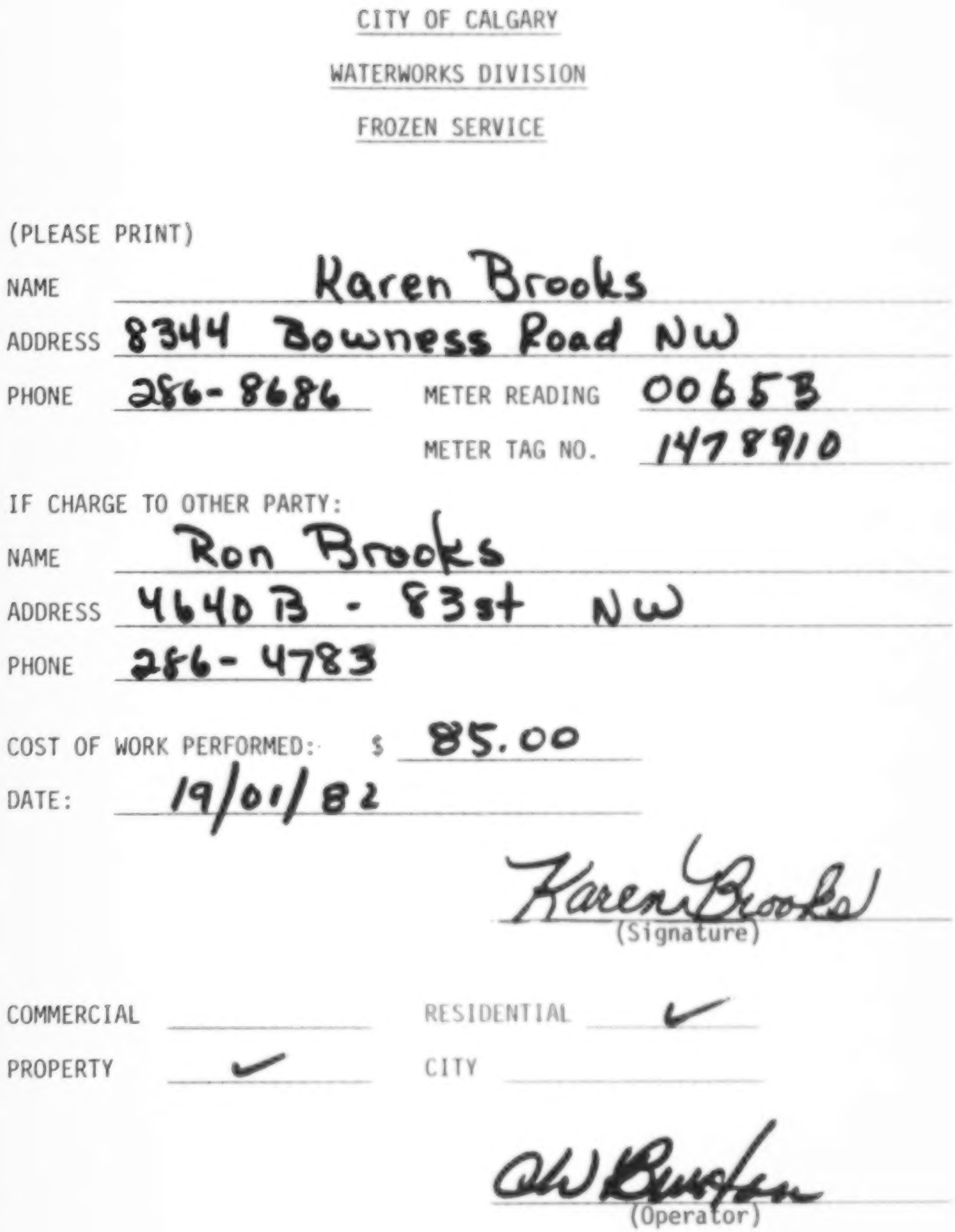


STEP #4 — Thawing cables clamped onto service keys when two services grounded on side of isolating main cock. Variation.



STEP #5 — Aircraft energizer used as power source. 600 AMP 12 volts recommended.

Fig. 5.31 Procedures to electrically thaw frozen water services



CITY OF CALGARY

WATERWORKS DIVISION

FROZEN SERVICE

(PLEASE PRINT)

NAME Karen Brooks

ADDRESS 8344 Bowness Road NW

PHONE 286-8686 METER READING 00653

METER TAG NO. 1478910

IF CHARGE TO OTHER PARTY:

NAME Ron Brooks

ADDRESS 4640 B - 83 st NW

PHONE 286-4783

COST OF WORK PERFORMED: $ 85.00

DATE: 19/01/82

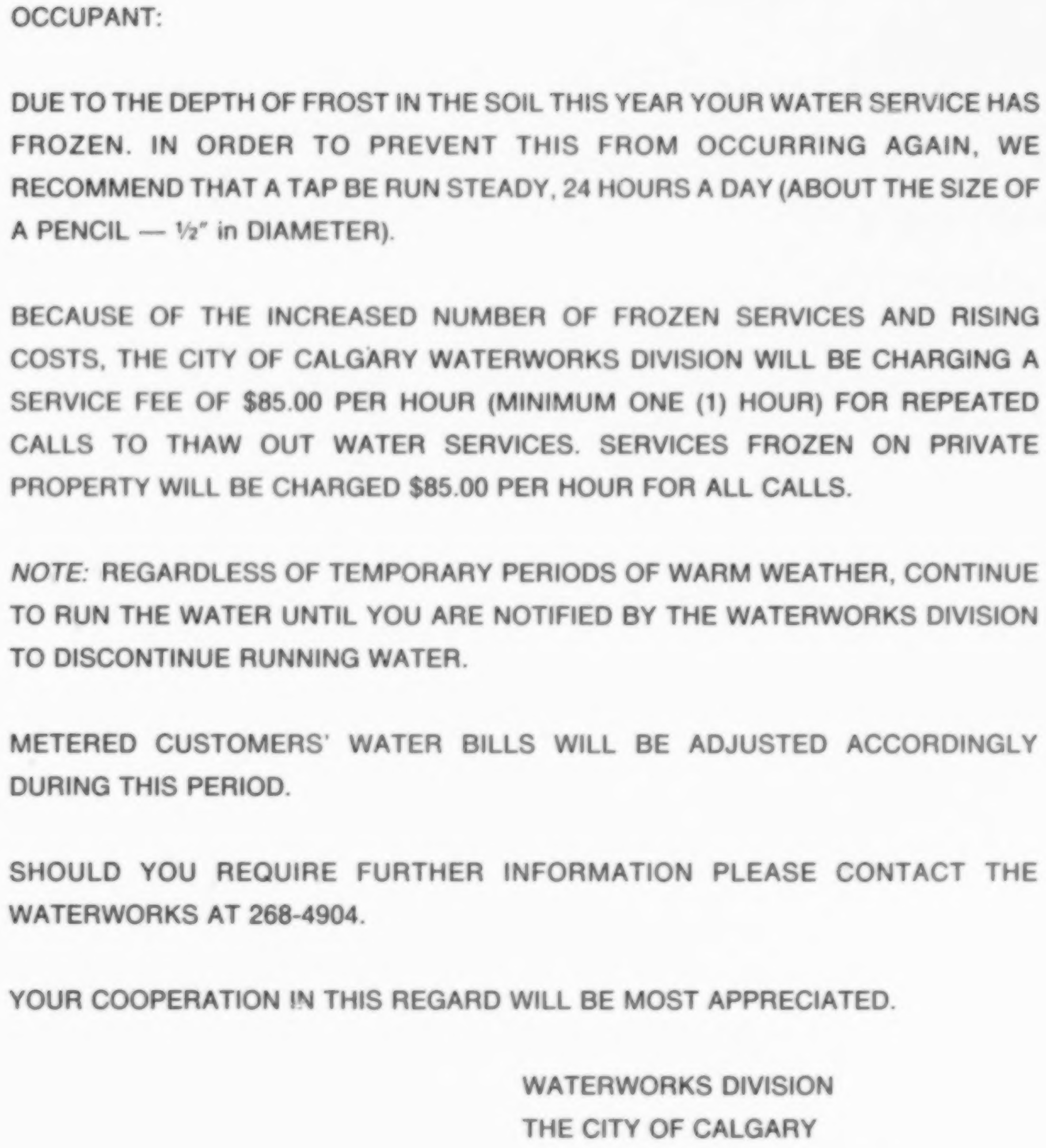
Karen Brooks
(Signature)

COMMERCIAL ____ RESIDENTIAL ✓

PROPERTY ✓ CITY ____

(Operator)

Fig. 5.32 Frozen service sheet



OCCUPANT:

DUE TO THE DEPTH OF FROST IN THE SOIL THIS YEAR YOUR WATER SERVICE HAS FROZEN. IN ORDER TO PREVENT THIS FROM OCCURRING AGAIN, WE RECOMMEND THAT A TAP BE RUN STEADY, 24 HOURS A DAY (ABOUT THE SIZE OF A PENCIL — ½" in DIAMETER).

BECAUSE OF THE INCREASED NUMBER OF FROZEN SERVICES AND RISING COSTS, THE CITY OF CALGARY WATERWORKS DIVISION WILL BE CHARGING A SERVICE FEE OF $85.00 PER HOUR (MINIMUM ONE (1) HOUR) FOR REPEATED CALLS TO THAW OUT WATER SERVICES. SERVICES FROZEN ON PRIVATE PROPERTY WILL BE CHARGED $85.00 PER HOUR FOR ALL CALLS.

NOTE: REGARDLESS OF TEMPORARY PERIODS OF WARM WEATHER, CONTINUE TO RUN THE WATER UNTIL YOU ARE NOTIFIED BY THE WATERWORKS DIVISION TO DISCONTINUE RUNNING WATER.

METERED CUSTOMERS' WATER BILLS WILL BE ADJUSTED ACCORDINGLY DURING THIS PERIOD.

SHOULD YOU REQUIRE FURTHER INFORMATION PLEASE CONTACT THE WATERWORKS AT 268-4904.

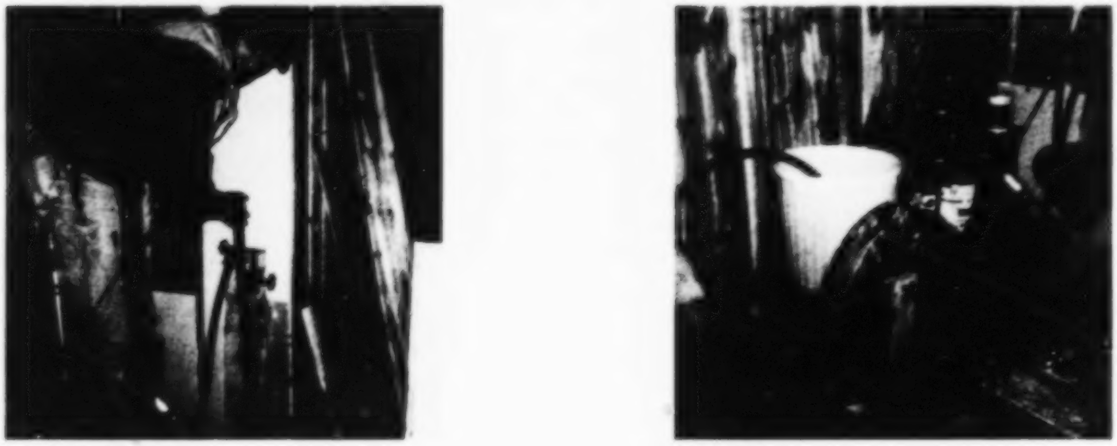
YOUR COOPERATION IN THIS REGARD WILL BE MOST APPRECIATED.

WATERWORKS DIVISION
THE CITY OF CALGARY

Fig. 5.33 City policy regarding frozen service

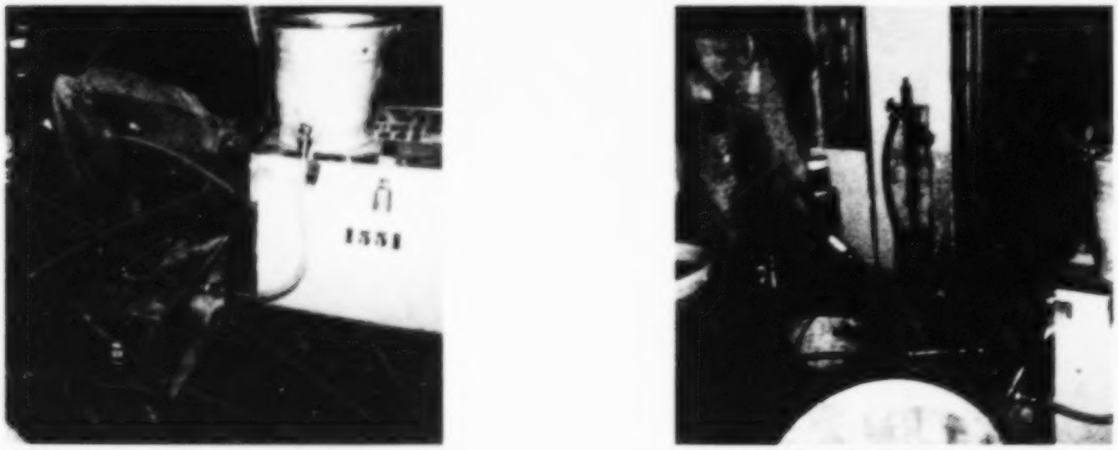
HOT WATER THAWING UNIT

STEP #3
Disconnnect service line below stop and waste.



STEPS #4 and #5
Install control head, feed in probe tube.

STEP #6
By-pass return into reservoir.



STEP #7
Hot water fed into pump.

STEP #9
Thawing complete. Probe tube removed.

Fig. 5.34 Procedures used to thaw lines with a hot water thawing unit

Feed probe tubing into service line until ice blockage is felt. Start pump and feed the probe tube in gently. (*NOTE: do not use force.*) You will feel the probe tube cutting its way through the ice.

9. When probe tubing is through ice.

   When probe tubing breaks through the ice, water will pass through the by-pass hose rapidly, indicating that the line has been thawed. Tighten the gland nut to prevent excess leakage. Place footage marker clip on tubing at this point to establish location of problem area. Water pressure will force the tube back through the gland.

10. Pull back probe and close service valve.

    Close service valve only after tubing has been pulled clear so the service valve will not cut off tubing.

11. Reconnect service line.

    Remove probe tubing completely and reconnect service line as quickly as possible. Turn on service valve and stop and waste and let water run at a steady flow (size of a pencil) to prevent re-freezing. If consumer is on a water meter, notify the meter department of present reading so consumer is charged flat rate for duration of potential freeze up. Consumer is issued a directive when to discontinue running water.

12. Complete required paperwork.

    Complete Frozen Service Sheet (Figure 5.32) as to address and to whom the thawing service is to be charged. The consumer pays when the service is frozen on the property. The utility is responsible where the service is frozen on utility property. Turn in paperwork to Thawing Supervisor as soon as possible.

C. Steam Thawing Service Valves, Main Valves and Hydrants

1. Steam thawing equipment (Figure 5.35).

   Portable steam boilers of about 8 to 10 horsepower (6 to 7.6 kW) are commonly used for thawing. These boilers may be mounted vertically on a truck and have a working pressure of 120 psi (827 kPa or 8.4 kg/sq cm). These units are completely self contained and can be mounted on one-ton dual-wheeled trucks.

2. Thawing valves.

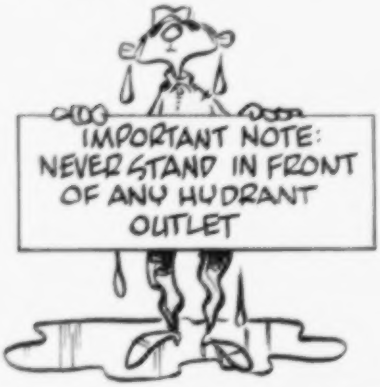
   Thawing of main and service valves is done with approximately 8-foot (2.5 m) long, ⅜-inch (10 mm) diameter metal tube attached to the one-inch (25 mm) steam hose. The tube is fed down the valve casing to the valve. The time required to thaw a frozen valve will depend on size and depth of frost. Two hours is not an unreasonable time to thaw a 10 or 12-inch valve (250 or 300-mm valve). This method could also be used to blow debris, small rocks and mud out of valve casings.

3. Thawing of fire hydrants.

   Steam boilers are equipped with a 30-foot (10 m) long and one-inch (25 mm) diameter steam hose. This hose is used for thawing and also for siphoning the water out of a hydrant body.

   The hydrant is thawed through a hydrant outlet if it is a pumper hydrant. The pumper outlet could be used also.

   a. Make sure hydrant is in off position before thawing process.



   b. Insert steam hose into hydrant through hydrant outlet. Siphon water out first, then thaw to bottom of hydrant and make sure the hydrant is operable.

   c. If hydrant is not draining, siphon out all the water to prevent re-freezing. Notify the Hydrant Repair Foreman if you have problems operating the hydrant or if the hydrant is not draining properly. A *"FIRE USE ONLY"* sign may have to be attached to one of the hydrant outlets until the hydrant is repaired.

4. Steam thawing frozen water mains.

   a. The frozen section of the main to be thawed should be isolated (turned off at main valve).

   b. Expose the main by excavating at 130-foot (40 m) intervals and cut out a section [approximately 3 feet (1 meter)]. Push the steam hose up the main with the aid of a one-inch (25 mm) steel snake.

   c. After the thawing process is completed each way from the cut out sections, turn on main valves very slightly to make sure water is flowing freely; turn off main valves and reconnect the cut out section with approved couplings.

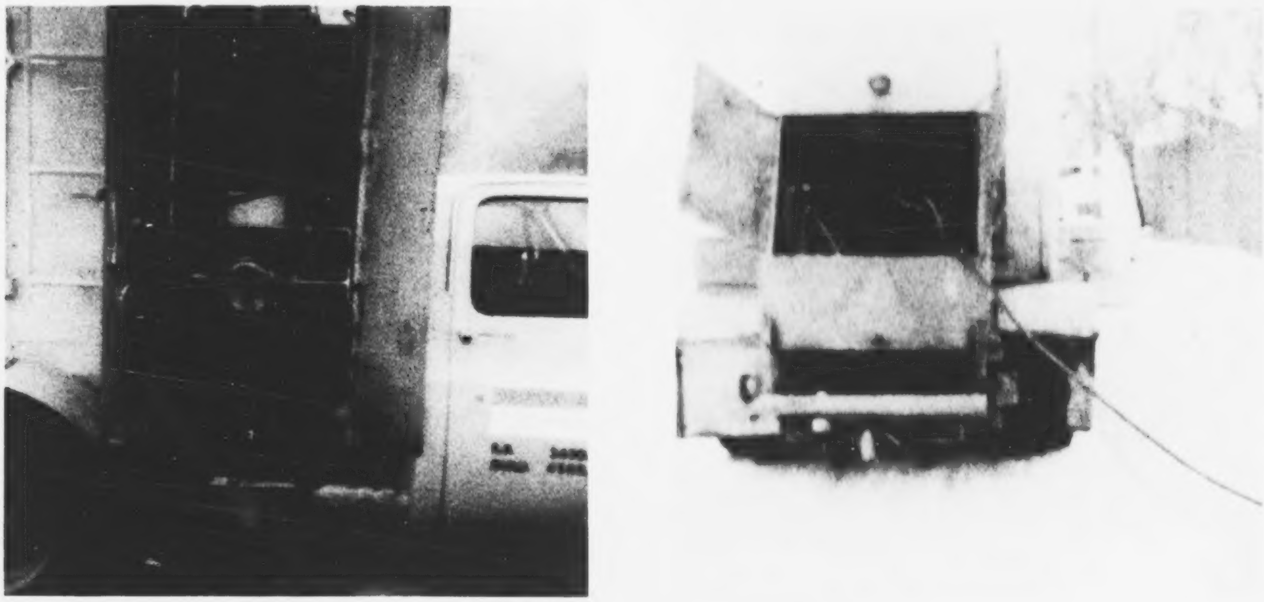
   d. After the main is reconnected, make certain the main is put on the flushing program. This procedure is used to thaw large services.

D. Flushing the Water Mains to Prevent Freezing

A water main flushing program should be developed and carried out each winter to prevent freezing of water mains in problem areas where mains have frozen in the past. The need for flushing is based on whether mains have frozen in the past, the depth of frost penetration, the type of soil, the depth of the main and the flow in the main. Another important factor is the temperature of the water in the main.

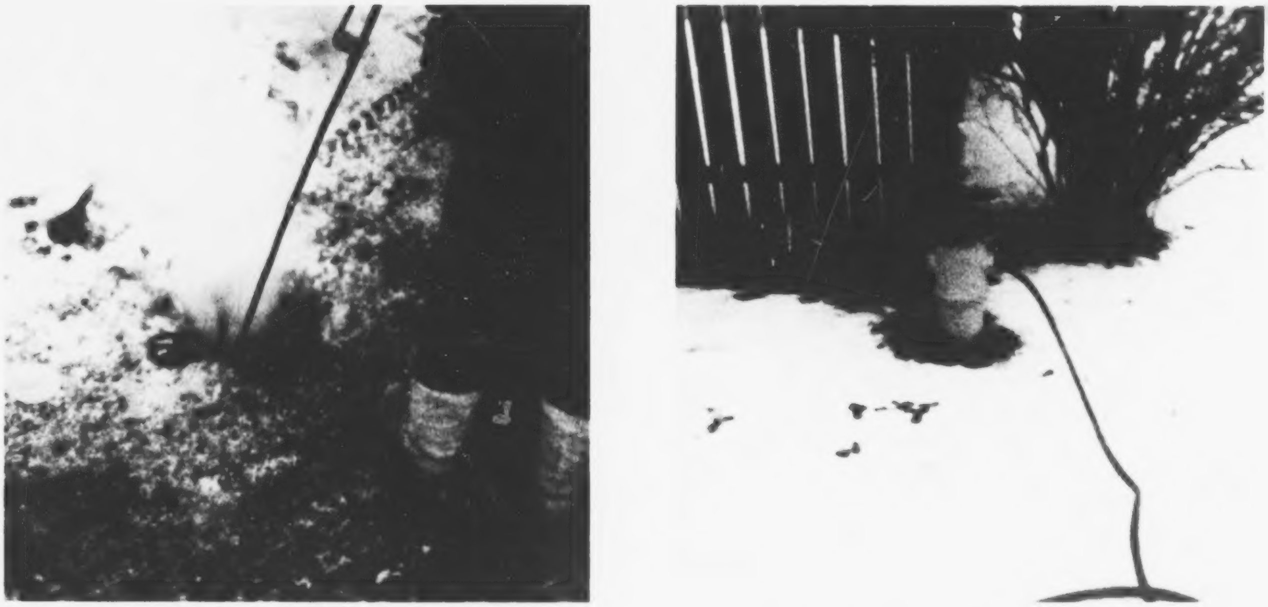
1. Spot check problem areas.

   Spot check problem areas for evidence of ice or slush in water mains. This should be done when records indicate severe frost penetration.



Truck-mounted steam boiler

Water tank, diesel fuel tank and steam hose



Thawing main valve

Thawing hydrant and siphoning out water

Fig. 5.35 Steam thawing unit

2. Dispatch crews.

   Once the need for the flushing program has occurred, dispatch flushing crews to assigned locations with properly marked maps or flushing diagrams. Be sure crews notify their flushing foremen and/or waterworks dispatcher of their flushing locations. The flushing foreman and/or dispatcher should be notified in case any complaints from consumers are received regarding loss of water pressure, no water, sanitary sewer backup into home (sewer being flushed into), or any other problem that could be caused by the flushing operation.

3. After crew arrives at flushing location.

   a. Check all main valves, hydrant control valves, hydrants and washouts to ensure all are in operating condition.

   b. If any valves or hydrants are frozen and cannot be thawed with a tiger torch, notify the flushing foreman or contact steam boiler crew to thaw valves or hydrants.

   c. Check catch basins and manholes that will be used to make sure that water will flow away freely. If any sewer installation is found frozen and cannot be used and there are no alternatives, notify flushing foreman to have Sewer Division thaw them out.

4. Prepare for flushing (labeled Step 4 on Figure 5.36).

   a. Operate main valves to positions indicated on flushing diagram.

   b. Attach gate valve in closed position to designated hydrant as per flushing diagram. Make sure all other outlets on hydrant are on tight. Open hydrant slowly to full open position, then open gate valve slowly to let out the air from hydrant.

      NOTE: Make sure hydrant is in full open position so water cannot escape through drain hole, thereby causing the drainage bed to freeze.

   c. Attach 2½-inch (63 mm) fire hose to gate valve and attach nozzle to other end of hose. Secure fire hose nozzle to catch basin or to manhole step so it will not whip when under pressure (Figure 5.37).

   d. Open gate valve slowly to full open position.

   e. Either visually or by feel with hand on hose, determine if ice is present in water main during flushing.

      NOTE: Ice may be present at start due to poor hydrant drainage or ice being formed in hydrant body.

      Allow 15 minutes of flow before test. When determining the presence of ice by feel, grip the hose firmly with bare hand. If ice is present you will feel it pass through. Also, by placing an ear to the hose you could hear a rattling sound as ice passes through, or by using a pail to catch the water flow, you can visually determine the presence of ice or slush. Record all results on reverse side of flushing diagram.

5. Operate main valves.

   a. Operate main valves as per flushing diagram. Operate valves slowly.

   b. Flush each phase for a minimum of 30 minutes or until no ice is evident. Record results of each phase.

   c. Continue flushing and recording results until each phase is complete.

   d. After all phases have been completed, return all valves to open position unless otherwise noted.

      NOTE: Do not leave open valves that are indicated to be closed for pressure separation.

   e. *IMPORTANT*

      Make sure all valves that should be open are open to maintain water circulation through water main and to avoid dead ends as this will cause the water main to re-freeze quickly.

   f. Any valves that are frozen in a closed position must be referred to the steam boiler crew to be thawed out and opened as soon as possible.

   g. Ensure that plastic discs are re-inserted under valve lid in top boxes to prevent snow, gravel and other debris from filling up casing, thus making it difficult to get at the rod.

6. Shut off hydrant (labeled Step 6 on Figure 5.37).

   a. Turn off gate valve slowly to avoid creating water hammer.

   b. Disconnect and drain fire hose, remove nozzle and roll up hose so no water remains in hose to eventually freeze up.

   c. Shut off hydrant slowly to again avoid water hammer. At this time open gate valve to allow air in so hydrant can drain. If hydrant is draining, there will be suction at gate valve when hand is placed over outlet.

   d. If hydrant is not draining, pump out by using the 12-volt pump with suction and discharge hoses attached. If any problem with pumping occurs, notify flushing foreman to obtain steam boiler to siphon water out.

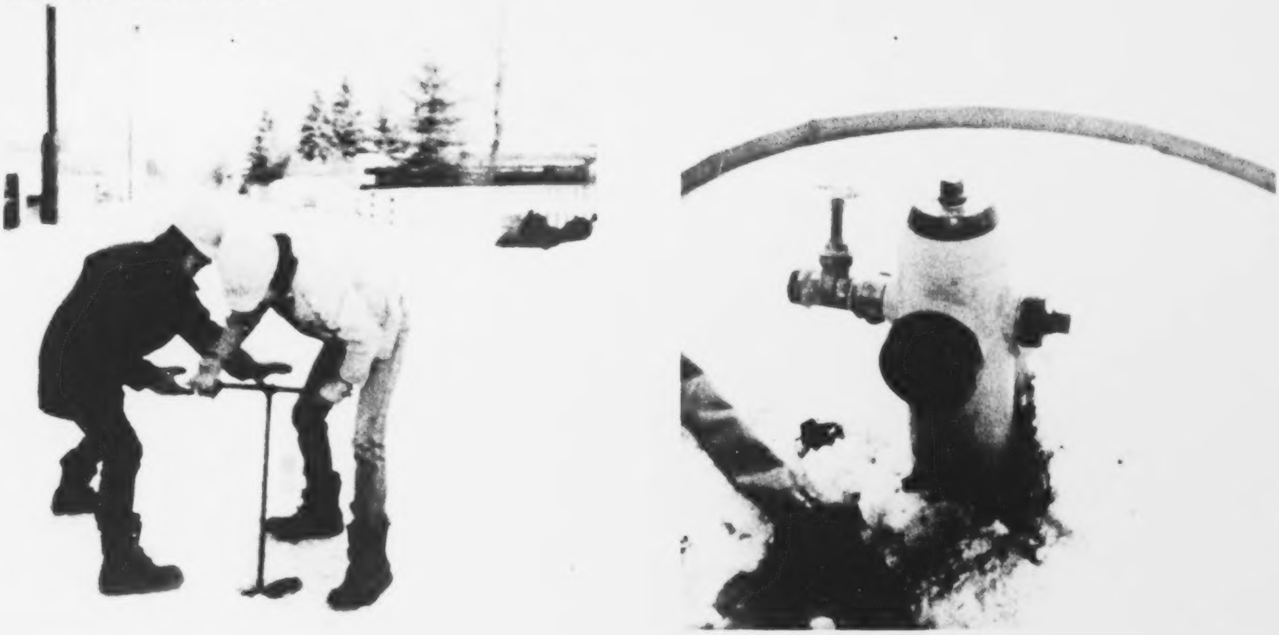
   e. If a problem occurs with operation of hydrant, refer to hydrant repair foreman. Provide foreman with make and location of hydrant. Also request the repairs to be made as soon as possible because they will be required for flushing.

   f. Ensure all gate valves and fittings, hose couplings and nozzles are free of ice and are not damaged. Any frozen or damaged fittings will hinder the next hookup, also causing leaks and creating hazardous conditions.

   g. All gate valves and pumps should be kept in a warm place to prevent them from freezing and splitting.

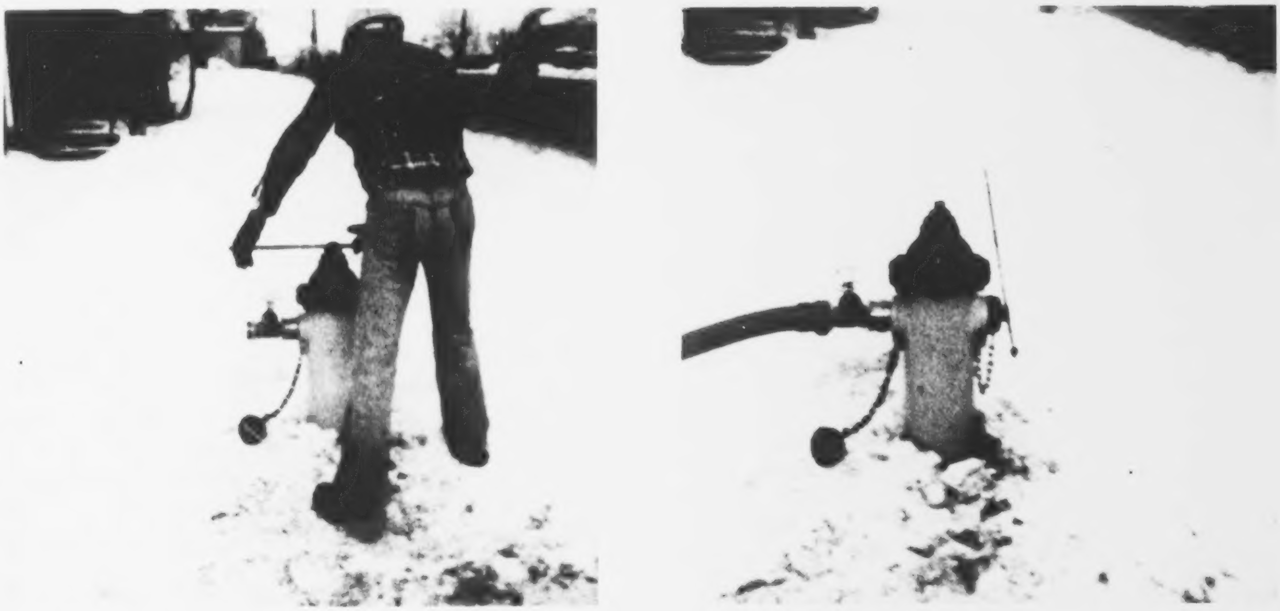
   h. If any water has been spilled on sidewalks or roadways, flushing foreman should be notified so the location can be sanded or salted.

   i. Ensure all manhole lids or catch basin grates that were disturbed have been replaced and secured.



STEP #4 - (a)
Operate main valves as per flushing diagram.

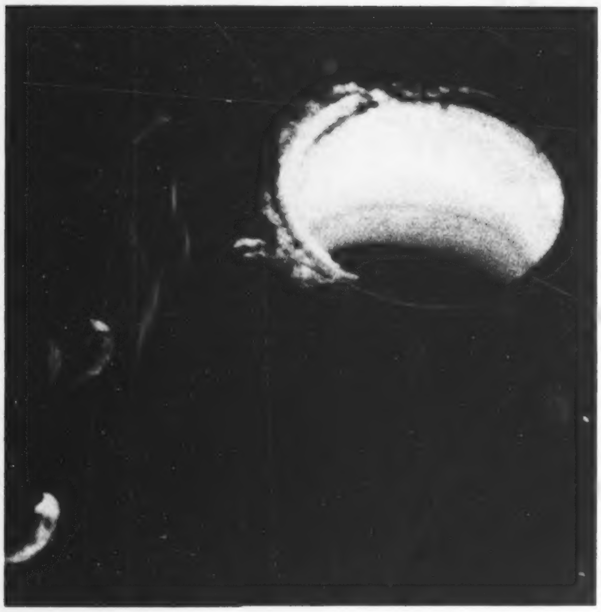
STEP #4 - (c)
Attach hose to gate valve



STEP #4 - (b)
Attach closed gate valve to hydrant, release air pressure

STEP #4 - (b)
Attached closed gate valve.

Fig. 5.36 Preparing to flush water mains to prevent freezing



STEP #4 - (c)
Attach nozzle to hose.

STEP #4 - (c)
Secure nozzle to manhole or catch basin.

STEP #4 - (c)
Secure nozzle to manhole or catch basin.

STEP #6 - (b)
Shut off hydraint. Disconnect fire hose and drain.

Fig. 5.37 Flushing water mains to prevent freezing

   j. Clean up flushing site. Pick up all traffic signs and warning devices that were used. Check to make sure all tools have been picked up, are in good working order and in their proper place or container.

7. Proceed to next flushing diagram.

   Proceed to next location. Notify flushing foreman and repeat procedure. At end of shift, notify flushing foreman if any minor problems have to be looked into.

E. Additional Reading

   GROUNDING, LOCATING AND THAWING PROCEDURES FOR WATER MAINS AND SERVICES, by Uni-Bell Plastic Pipe Association, 2655 Villa Creek Drive, Suite 164, Dallas, Texas 75234.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.70V Why is the freezing of service lines a greater problem than with mains?

5.70W How can a frozen water main be thawed?

5.70X What precaution should be exercised when thawing pipe using electrical thawing methods?

End of Lesson 2 of 4 Lessons
on
DISTRIBUTION SYSTEM OPERATION and MAINTENANCE

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 2 of 4 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 1.

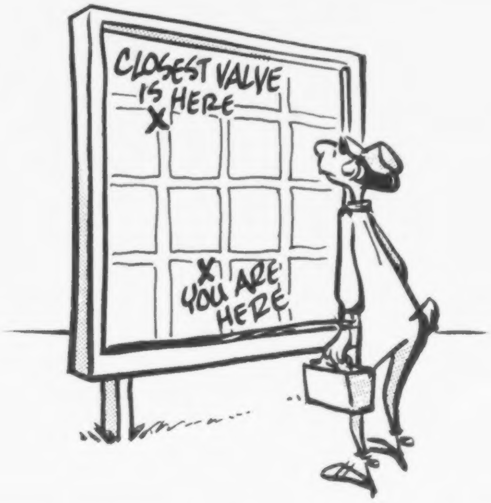
11. Why must water mains be maintained?
12. Why should water utilities have a leak detection program?
13. What are the advantages of wet tapping over dry tapping?
14. How can potential distribution system failures be recognized in advance?
15. What information can be obtained from pipe roughness coefficient (C Factor) tests?
16. What problems may be created if distribution system lines are not regularly flushed?
17. If flushing fails to clean pipes, what alternative methods might be effective?
18. How is water provided to consumers while a water main is being lined?

CHAPTER 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 3 of 4 Lessons)

5.71 Valves

Distribution system shut-off valves are provided primarily to isolate small areas for emergency maintenance. Most of these valves, therefore, suffer from lack of operation rather than from wear. A comprehensive program of inspection, exercising and maintenance of valves on a regular basis can help water utilities avoid potentially serious problems when the need to use a valve arises.



Operators should know *EXACTLY* where to go to shut off any valves at any time in case of a line break or other emergency. When breaks occur in water mains, crews often experience problems in *FINDING* valves whose locations are marked incorrectly on system maps. Other problems include valves that won't close or open after they are located. Time is often wasted looking for valves and after finding them getting them to work. The same devices used to locate mains are used to locate valves that may be lost or buried under earth or snow.

Routine valve inspections should be conducted and the following tasks performed:

1. Verify the accuracy of the location of the valve boxes on the system map (if incorrect, *CHANGE THE MAP*),
2. After removing the valve box cover, inspect the stem and nut for damage or obvious leakage,
3. Close the valve fully, if possible, and record the number of turns to the fully closed position,
4. Reopen the valve to reestablish system flows, and
5. Clean valve box cover seat. Sometimes covers on valve boxes will come off when traffic passes over them due to dirt in the seat.

Exercising (opening and closing a valve) should be done at the same time the valve inspection is made. Some manufacturers recommend that a valve stem never be left in a fully open or closed position. They recommend that after fully opening or closing a valve, back off the stem by one turn.

Conditions of each system will determine how often the valves should be exercised, but in general it is recommended that all valves be exercised at least once a year. Planned exercising of valves verifies valve location, determines whether or not the valve works and extends valve life by helping to clean encrustations from the valve seats and gates. Any valves which do not completely close or open should be replaced. Valves which leak around the stems should be repacked. To determine that a valve is closed, an aquaphone or other listening device can be used. Valves should be exercised in both directions fully closed and fully opened and the number of turns and direction of operation recorded. Valves operating in a direction opposite to that which is standard for the system need to be identified and this fact recorded. The condition of the valve packing, stem, stem nut, and gearing should be noted. A timely maintenance program should be initiated to correct any problems found during the inspection and exercising.

Two types of hydraulic problems can occur while operating a valve, cavitation (CAV-uh-TAY-shun) and water hammer. Cavitation results when a partial vacuum (voids) occurs on the downstream side of a valve and a small section of the pipe is filled with low-pressure vapor pockets from the water. These pockets will collapse downstream (implode) and in doing so create a mechanical shock that causes small chips of metal to break away from the valve surfaces. A noisy or vibrating valve may be an indication that cavitation is occurring and the valve may eventually have to be replaced if cavitation is permitted to go on indefinitely. Water hammer is caused by closing a valve too quickly. The water flow is suddenly stopped, shock waves are generated, and the resulting large pressure (even though very brief) increases throughout the system can result in significant damage. Water hammer can be prevented by always closing the valves slowly, regardless of size or type.

Valves can be operated either manually or by a power actuator. Manual operation of large valves not only can be back-breaking labor, but is a slow process and, therefore, time consuming and costly. Power equipment (Figures 5.38 and 5.39) is available which will cut valve operating time considerably. Most types of power equipment are portable, fast and efficient and can be powered by a portable air compressor, an electric generator, or a gas engine. A power valve operator can also be used to accurately count the number of turns to open or close a valve.

One of the most important factors in maintaining distribution system valves is the availability of current and correct maps of the distribution system. A portion of a typical distribution system map for valves and hydrants is shown in Figure 5.40. Each utility should use this type of map, verify often that it is accurate, and keep the map up-to-date of any changes such as replacements or additions. Some water departments equip their service trucks with "gate books" which carry all of the pertinent valve information including location, direction of turning to close, and number of turns required.

Maintaining current records is as important as maintaining current maps. A typical two-sided valve record form is shown in Figure 5.41. The location of a valve is obtained from a controlled survey bench mark or permanent reference point. The make of valve is important because different makes have different operating characteristics. The use of a simple valve numbering system keyed to up-to-date maps is recommended. This procedure has proven to be quite helpful in locating valves rapidly and in communicating with others about particular valves.

Road improvements require constant attention from water distribution system operators to insure that valves are not lost. Valve boxes can be graded out or covered with pavement. The center lines of roads, curb lines, and right-of-way lines used as reference points for locating valves can be changed. Changed measurements must be noted on valve record forms.

Corrosion is a problem for valves in some areas and can cause failure of bonnet and packing gland bolts. This is apparent when stem leakage occurs or when a valve is closed and the bonnet separates from the body. Stainless steel bolts can be used for replacement, and the valve should be encased in polyethylene wrap.

Valves left closed in error can cause severe problems in a distribution system. Construction and maintenance crews operate valves as they do their work. Contractors and plumbers sometimes operate valves without permission. Separate pressure zones in distribution systems may be established by closing valves, thus increasing the possibility of problems related to the incorrect use of valves. Unexplained problems with pressure and excessive operation of pumps in a given area have been traced to valves left closed or open in error. When crews change shifts during a project, valve closures and openings information must be exchanged. Crew chiefs must be sure all valves are restored to proper positions whenever anyone discovers a valve in the wrong position.

Repairing in-line (installed) gate valves is a difficult task. If repairs are needed, proper advance planning is important. The valves needing repairs must be located. The valves that will be used to isolate a damaged valve must be in good operating condition. The necessary repair parts must be obtained in advance. When ordering repair parts, be sure to include the size, make, direction of opening, year of manufacturer, and other pertinent information in order to assure that the proper repair parts will be received.

Until the valve is isolated and opened up, it is difficult to determine what part of the valve is damaged. Therefore, make sure that all replacement parts are available before isolating the necessary section of the water main, excavating the valve, and making the repairs.

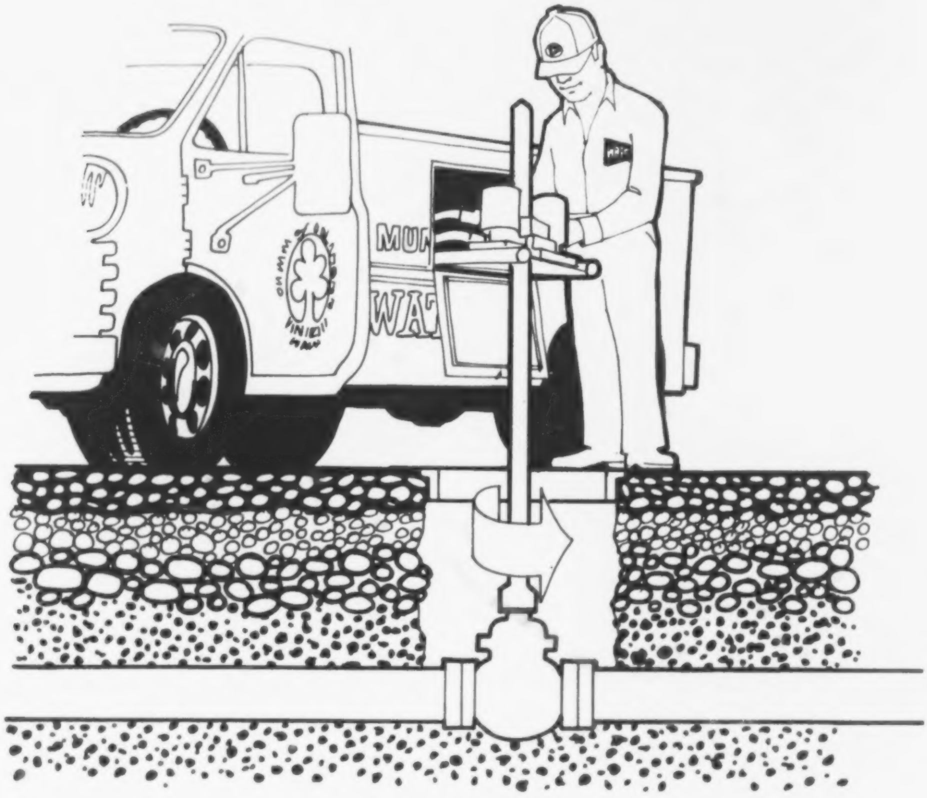


Fig. 5.38 How powered valve operators work

(Permission of E. H. Wachs Company)

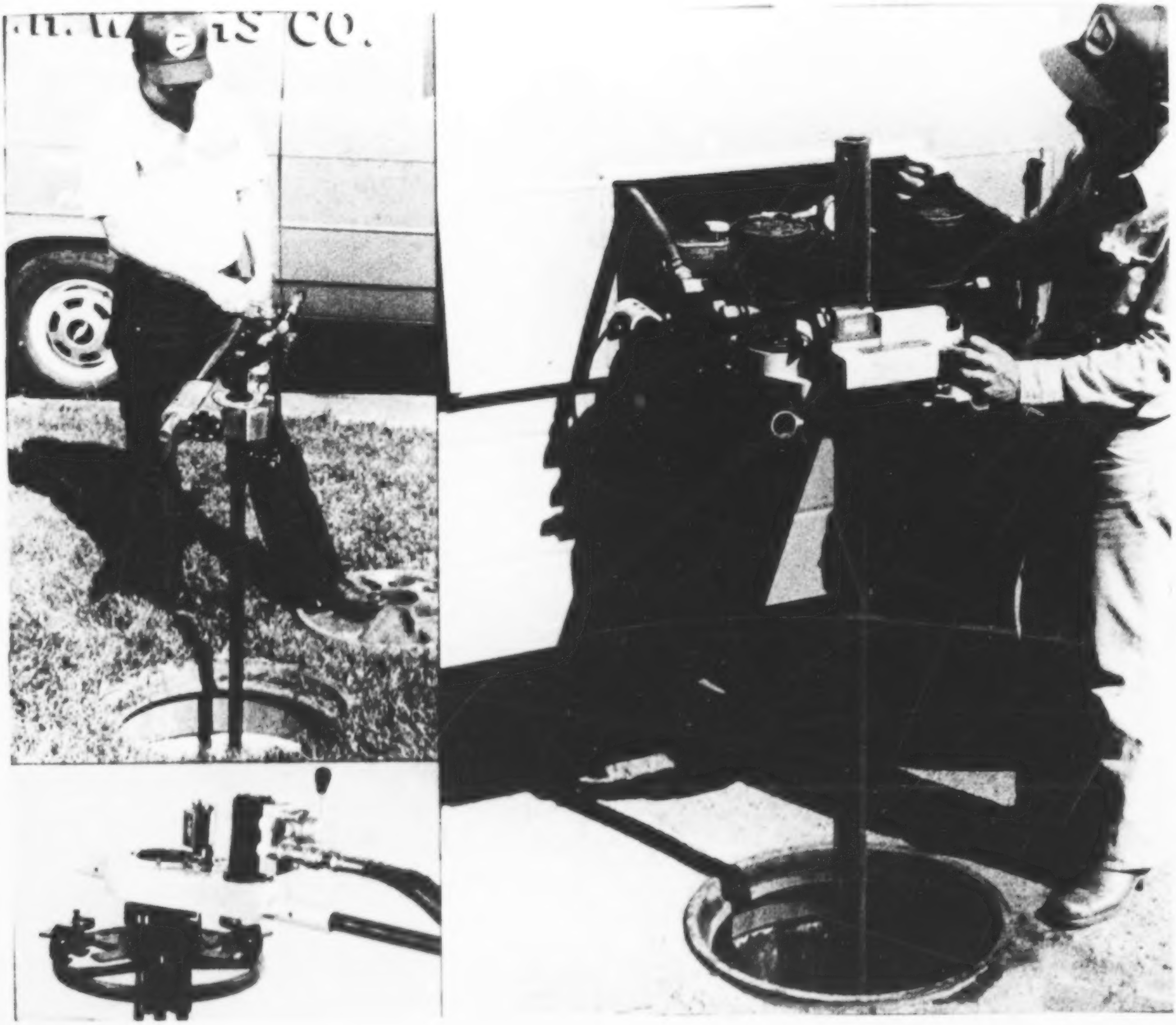


Fig. 5.39 Portable and truck-mounted powered valve operators

(Permission of E. H. Wachs Company)

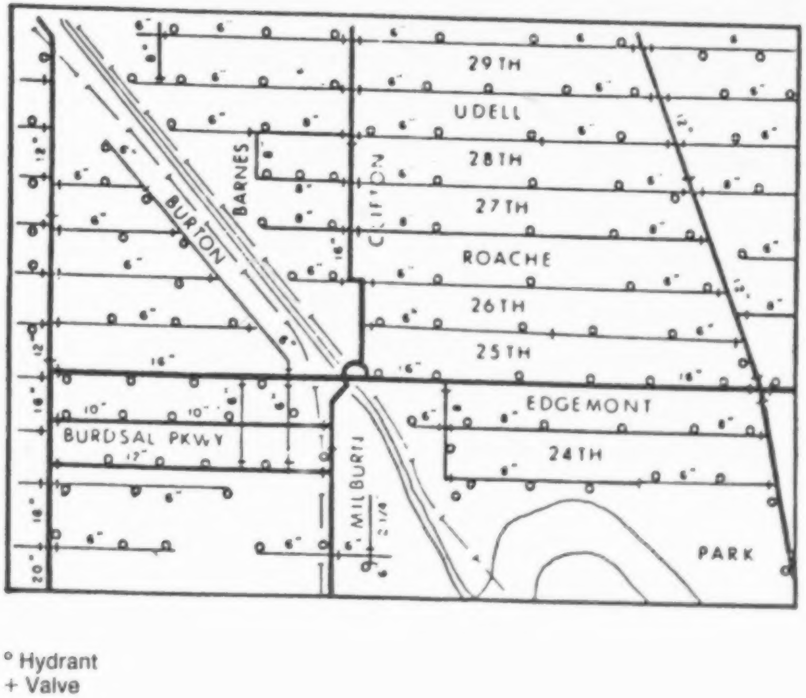
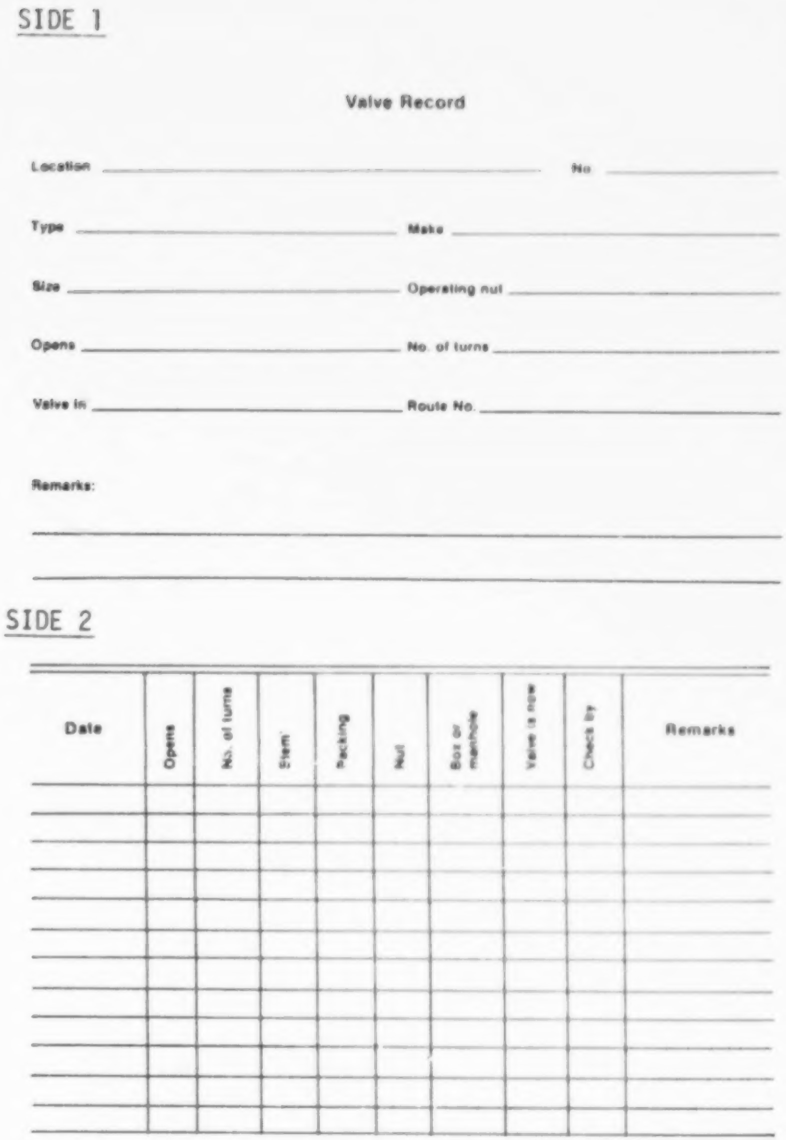

29TH
UDELL
28TH
27TH
ROACHE
26TH
25TH
EDGEMONT
24TH
BURTON
BARNES
CLIFTON
BURDSAL PKWY
MILBURN
PARK
6"
10"
12"
16"
20"
° Hydrant
+ Valve

Fig. 5.40 *Portion of a valve and hydrant map with street names and main sizes given*

(Reprinted from *OPFLOW*, by permission. Copyright 1977, The American Water Works Association)



SIDE 1

Valve Record

Location ______________________ No ______________

Type ______________________ Make ______________

Size ______________________ Operating nut ______________

Opens ______________________ No. of turns ______________

Valve in ______________________ Route No. ______________

Remarks:

____

____

SIDE 2

Date	Opens	No. of turns	Stem	Packing	Nut	Box or manhole	Valve is now	Check by	Remarks

Fig. 5.41 *Typical (two-sided) valve record form*

(Reprinted from *OPFLOW*, by permission. Copyright 1977, The American Water Works Association)

Most valves are located along roadways, and operators who locate, exercise, or dig up valves for repair are exposed to traffic hazards. Routine work is usually done during daylight, but traffic must be warned at all times. Motorists must be notified in advance of blocked lanes or work along side of traveled lanes. This can be done by using high-level warning signs, barricades with lights for night work, traffic cones, warning flags, and flagmen. Repair crew vehicles with flashers can be positioned to alert traffic and to provide physical protection for the crew from oncoming traffic at the work site. Supervisors should hold a job-site meeting with operators to explain the task, the equipment to be used for the job, the hazards, the safety procedures to follow and the safety equipment needed.

For additional information on valve maintenance, see Chapter 18, Maintenance, Section 18.26, "Valves," in *WATER TREATMENT PLANT OPERATION*, Volume II, in this series of manuals.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.71A How can water utilities avoid serious valve operating problems?

5.71B Why should operators be able to quickly find valves?

5.71C Why should valves be exercised regularly?

5.71D How can you tell if cavitation is occurring at a valve?

5.72 Fire Hydrants

The different types of hydrants available are described in Chapter 3, "Distribution System Facilities." Operators responsible for hydrant inspections should be thoroughly familiar with the various types of hydrants used in their system. If questions which are difficult to answer arise about the fire hydrant or its operation, a good source of information is the hydrant supplier. Contact the supplier whenever necessary to obtain descriptive literature, operation and maintenance instructions, parts manuals or assistance on particular problems.

In general, fire hydrants should be inspected and maintained twice a year. These operations are often done in the spring and the fall. However, each hydrant should also be inspected after each use. Inspect dry-barrel hydrants after use, especially during freezing weather, to assure that the drain remains open when the hydrant is not in use.

A good source of information on fire hydrants is AWWA's Manual M17, *INSTALLATION, OPERATION, AND MAINTENANCE OF FIRE HYDRANTS.*[16] The operator is referred to this manual for detailed procedures.

Some general inspection and maintenance procedures used for hydrants include:

1. Inspect for leakage and make corrections when necessary.
2. Open hydrant fully, checking for ease of operation.
3. Flush hydrant to waste (take care to direct flow).
4. Remove all nozzle caps and inspect for thread damage from impact or cross threading. Wire-brush the nozzle and cap threads. Clean and lubricate outlet nozzle threads, preferably with a dry graphite base lubricant, and check for ease of operation. Be sure that the outlet nozzle cap gaskets are in good condition.
5. Replace caps, tighten with a spanner wrench, then back off on the threads slightly so that the caps will not be excessively tight but will leave sufficient frictional resistance to prevent removal by hand.
6. Check for any exterior obstruction that could interfere with hydrant operation during an emergency.
7. Check dry-barrel hydrants for proper drainage.
8. Clean exterior of hydrant and repaint if necessary.
9. Be sure that the auxiliary valve is in the fully opened position.
10. If a hydrant is inoperable, tag it with a clearly visible marking to prevent loss of time by fire fighting crews if an emergency should arise before the hydrant is repaired. Immediately report the condition of this fire hydrant to your fire department.
11. Prepare a record of your inspection and maintenance operations and any repair work. A recommended Hydrant Maintenance Report and Master Record are shown in Figure 5.42.

Everyone working with hydrants should be aware that when operating a dry-barrel hydrant, it must be opened completely so that the drain will become *FULLY* closed. If this is not done, the drain will remain partially open and water seeping through it could saturate the drain field and result in hydrant damage from freezing.

Hydrants can be partially protected against freezing by covering them with a box which can be quickly removed when the hydrant must be used. To keep hydrants from freezing that won't drain in the winter due to frozen conditions, use propylene glycol or some other eatable substance that won't freeze or cause water quality problems. Frozen hydrants may be thawed by same methods used for thawing pipe. Electric current thawing can be used. Live steam injected through a hose into the hydrant barrel is a relatively quick, inexpensive and effective method of thawing.

Standardization of hydrants minimizes the requirement for stocking parts, simplifies repair procedures, and allows replacing only defective parts. Every water utility should keep a basic stock of repair parts on hand for immediate use. If spare parts are not readily available, *YOUR* community's fire-protection system could be jeopardized.

The repair job most often performed on fire hydrants is replacing main valves. Therefore, try to keep an ample supply of main valves in your stockroom. Other important items to keep on hand are drain parts, seat rings, stem seals

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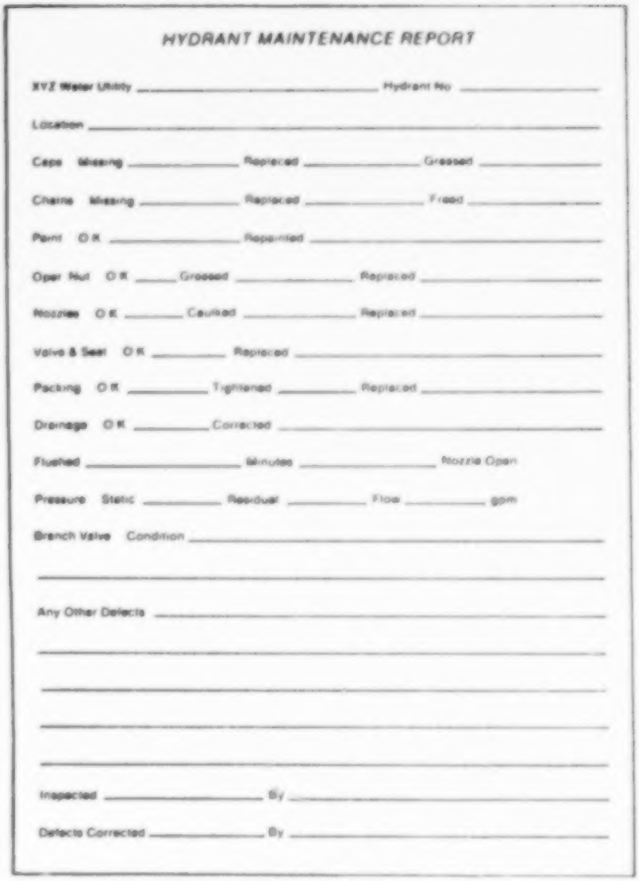
[16] *Obtain from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 30017. Price to members, $9.00; nonmembers, $11.00*



HYDRANT MAINTENANCE REPORT

XYZ Water Utility ______________ Hydrant No ________

Location ______________________________

Caps Missing ________ Replaced ________ Greased ________

Chains Missing ________ Replaced ________ Freed ________

Paint O K ________ Repainted ______________

Oper Nut O K ____ Greased ________ Replaced ________

Nozzles O K ____ Caulked ________ Replaced ________

Valve & Seat O K ______ Replaced ______________

Packing O K ______ Tightened ______ Replaced ________

Drainage O K ______ Corrected ______________

Flushed ____________ Minutes ____________ Nozzle Open

Pressure Static ______ Residual ______ Flow ______ gpm

Branch Valve Condition ______________________

____

Any Other Defects ______________________

____

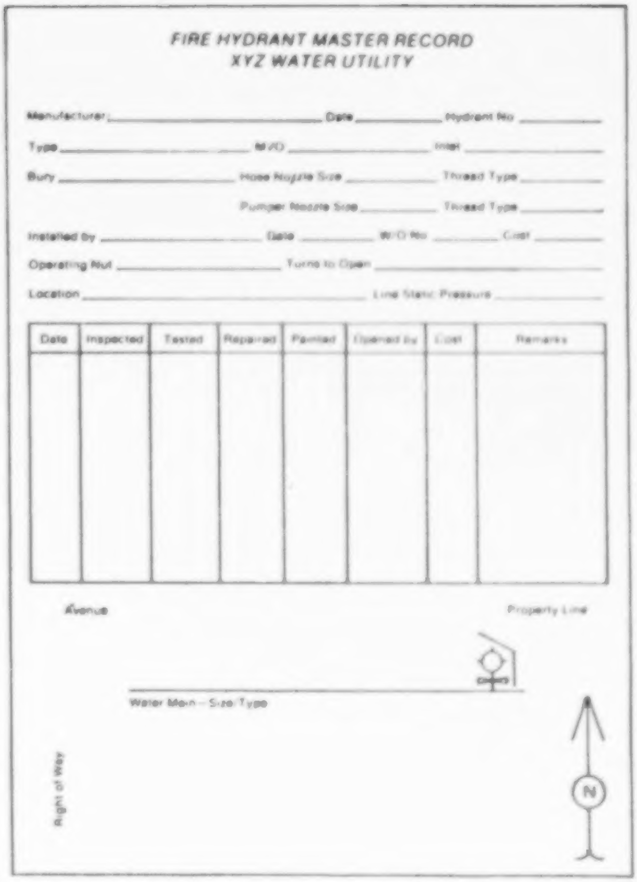
____

____

____

Inspected ____________ By ______________

Defects Corrected ________ By ______________



FIRE HYDRANT MASTER RECORD
XYZ WATER UTILITY

Manufacturer ______________ Date ________ Hydrant No ________

Type ____________ M/O ____________ Inlet ____________

Bury ____________ Hose Nozzle Size ________ Thread Type ________

Pumper Nozzle Size ________ Thread Type ________

Installed By ____________ Date ________ W/O No ________ Cost ________

Operating Nut ____________ Turns to Open ______________

Location ______________________ Line Static Pressure ________

Date	Inspected	Tested	Repaired	Painted	Opened by	Cost	Remarks

Avenue
Property Line
Water Main – Size/Type
Right of Way
N

In order to carry out a meaningful inspection and maintenance program, it is essential that each hydrant be recorded as to location, make, type, size, and date of installation.

Fig. 5.42 Hydrant maintenance report and master record forms

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and packing, and "traffic-damage" repair kits. These items should be stocked for each of the various types and sizes of hydrants in your system. The number of parts to keep on hand depends on the past experience of your water utility.

Fire hydrant vandalism causes serious problems for water utilities. Illegally opened fire hydrants cause damage due to flooding and washouts. Consumers can suffer damages due to a lack of water and pressure. Water may not be available to fight fires when needed and the loss of water results in a loss of revenue for the water utility.

Fire hydrant caps or guards can be installed on the tops of fire hydrants to eliminate fire hydrant vandalism.

Fire hydrants are usually the only part of the distribution system regularly seen by the general public. Frequent painting of hydrants creates a favorable impression and is, therefore, an excellent public relations tool.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.72A What information can be obtained from a fire hydrant supplier?

5.72B When should fire hydrants be inspected?

5.72C List some general fire hydrant inspection and maintenance procedures.

5.72D What happens when a dry-barrel hydrant is operated with the valve only partially open?

5.73 Meters

5.730 Testing of Meters

Water meters can over- or under-register because of wear, deposits, or turbulence resulting from valves and fittings. Over-registration rarely occurs. Each utility should establish a schedule for periodic meter testing based on meter use, water quality, age of meter, cost of testing and water revenue loss. The age of a meter reflects the degree of wear of the meter parts which also increase when the water is corrosive or abrasive. The potential revenue loss from inaccurate meters which almost always under-register must also be considered.

5.731 Test Procedures

Small meters should be tested once every five to ten years, and large ones every one to four years. New meters should also be tested before installation, although a survey of customer metering practices showed that 68 percent of the utilities surveyed did not test their meters before they were first put into use.

One type of meter testing installation used in a utility's shops is shown in Figure 5.43. Field testing is usually done only to meters larger than two inches (50 mm) in size. One method used in the field is to connect a calibrated test meter in series with the meter to be tested and then compare the readings of the two meters. Most of the larger meters have provisions for attaching a test meter. The smaller meters and some of the larger ones are generally tested by running a measured volume of water through the meter and then comparing the reading to the known volume used. Some larger meters have built-in calibration checks, such as a venturi meter with a test head which simulates pressure differential from a venturi tube.

Most modern water meters have sealed registers and easily changed measuring chambers. These meters are usually maintained and repaired by the utility. Older style meters with heads that must be worked on should be returned to the manufacturer for maintenance and repair if they are not being replaced.

FORMULAS

Domestic water service meters are called totalizing water service meters because they measure and record the total volume of water that passes through the meter to the consumer. Totalizing water service meters are tested at a *GIVEN RATE OF FLOW* as measured by a rotameter in gallons per minute. The rotameter measures the actual flow in gallons per minute (GPM) while the water service meter measures the *TOTAL VOLUME IN GALLONS.* Using the meter testing installation shown in Figure 5.43, we can determine the accuracy of a totalizing meter at both low and high flows as indicated by the rotameter.

To determine the actual volume of water that passes through a totalizer, calculate the volume of water that flows into a cylinder during the test time period.

Volume, cu ft = (Area, sq ft)(Diameter, ft)

and

Volume, gal = (Volume, cu ft)(7.48 gal/cu ft)

To calculate the actual rate of flow through the meter, divide the actual volume in gallons by the time in minutes.

$$\text{Actual Flow, GPM} = \frac{\text{Actual Volume, gal}}{\text{Time, min}}$$

Accuracy of meters is determined by dividing the observed meter values (rotameter or totalizer) by actual values and multiplying by 100 percent.

$$\text{Meter Accuracy, \%} = \frac{(\text{Observed Value})(100\%)}{\text{Actual Value}}$$

EXAMPLE 5

A water service meter is tested in the installation shown in Figure 5.43. The calibrated tank is 2 feet in diameter. The flow meter (rotameter) reads 1.5 GPM. The discharge valve on the tank is closed. A stop watch is started when the water level in the tank goes past the 1.00-foot mark and is stopped when the water level goes past the 3.00-foot mark. The stop watch reads 30 minutes and 55 seconds. What should the flow meter read in GPM and what should be the total volume of water recorded during the test? The meter reading at the start of the test (stop watch) was 112,474 gallons and was 112,520 gallons at the end of test.

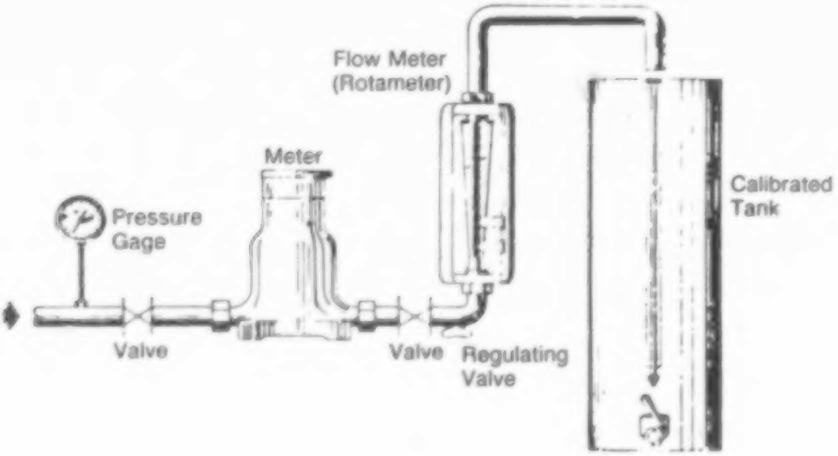


Fig. 5.43 Meter testing installation

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

KNOWN		UNKNOWN
Tank Diameter, ft	= 2.0 ft	Actual Flow, GPM
Flow Meter, GPM (Rotameter)	= 1.5 GPM	Actual Volume, Gal
Water Level, ft	= 1.0 ft (start)	
Water Level, ft	= 3.0 ft (stop)	
Time, min & sec	= 30 min, 55 sec	
Service Meter, gal	= 112,474 gal (start)	
Service Meter, gal	= 112,520 gal (stop)	

1. Calculate the volume of water measured by the cylinder in cubic feet.

$$\text{Volume, cu ft} = (0.785)(\text{Diameter, ft})^2(\text{Stop Level, ft} - \text{Start Level, ft})$$

$$= (0.785)(2\ \text{ft})^2(3.0\ \text{ft} - 1.0\ \text{ft})$$

$$= 6.28\ \text{cu ft}$$

2. Convert cylinder volume from cubic feet to gallons to find actual volume of water in gallons.

$$\text{Volume, gal} = (\text{Volume, cu ft})(7.48\ \text{gal/cu ft})$$

$$= (6.28\ \text{cu ft})(7.48\ \text{gal/cu ft})$$

$$= 47\ \text{gallons}$$

3. Determine volume of water measured by flow meter in gallons.

Meter Stop Reading, gal	= 112,520 gal
Meter Start Reading, gal	= 112,474 gal
Recorded Flow, gal	= 46 gal

NOTE: Since meter volume is slightly less than the volume measured in the cylinder, the meter under-registered.

4. Calculate the actual flow rate in gallons per minute.

$$\text{Actual Flow, GPM} = \frac{\text{Actual Volume, gal}}{\text{Time, min}}$$

$$= \frac{47\ \text{gallons}}{30\ \text{Min} + \left(\frac{55\ \text{sec}}{60\ \text{sec/min}}\right)}$$

$$= \frac{47\ \text{gallons}}{30\ \text{min} + 0.92\ \text{min}}$$

$$= \frac{47\ \text{gallons}}{30.92\ \text{min}}$$

$$= 1.52\ \text{GPM}$$

NOTE: Since the actual flow is slightly different than the meter flow, the meter is not perfect.

5.732 Accuracy Requirements

Table 5.1 shows the accuracy requirements for new meters. In most instances, the meter under-registers slightly to favor the customer.

TABLE 5.1 ACCURACY REQUIREMENTS FOR NEW METERS[a,b]

AWWA Standard Designation and Type of Meter	At Normal Test Flow, percent	At Minimum Test Flow, percent
C700-Displacement Type	98.5-101.5	95
C701-Turbine Type	98.0-102.0	Not required
C702-Compound Type[c]	97.0-103.0	95
C703-Fire Service Type[c]	97.0-103.0	95
C704-Propeller Type	98.0-102.0	95

[a] AWWA Standards, *OPFLOW*, Vol. 3, No. 8, August 1977, p. 3.

[b] There is no AWWA standard for the accuracy of repaired meters, but the practice at many utilities is to require the same accuracy as for new meters at the normal test flow and at least 90 percent at the minimum test flow.

[c] The accuracy during the "change-over period," which is defined in the applicable standards, shall not be less than 85 per cent.

EXAMPLE 6

If a totalizing water service meter reads 46 gallons and the actual flow calculated by the use of a calibrated tank was 47 gallons, did the meter meet the accuracy requirements for a displacement type of meter as listed for new meters in Table 8.1?

Known		Unknown
Meter Reading, gal	= 46 gal	Does the meter meet accuracy requirements?
Actual Volume, gal	= 47 gal	

Calculate the accuracy of the meter.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, gal})(100\%)}{\text{Actual Volume, gal}}$$

$$= \frac{(46\ \text{gal})(100\%)}{47\ \text{gal}}$$

$$= 97.9\%$$

NOTE: Since the meter accuracy (97.9%) is not within the accuracy required (98.5 to 101.5%), the meter does not meet the accuracy requirements.

EXAMPLE 7

If a rotameter reads 1.5 GPM and the actual flow calculated by the use of a calibrated tank was 1.52 GPM, what was the accuracy of the meter?

Known		Unknown
Meter Reading, GPM	= 1.5 GPM	Meter Accuracy, %
Actual Flow, GPM	= 1.52 GPM	

Calculate the accuracy of the meter.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, GPM})(100\%)}{\text{Actual Flow, GPM}}$$

$$= \frac{(1.5 \text{ GPM})(100\%)}{1.52 \text{ GPM}}$$

$$= 98.7\%$$

5.733 Meter Registers and Readouts

Meter registers may be mechanically or magnetically driven. In the older type of mechanically driven registers, a series of gears within the meter transmits the rotary motion of a disc or piston to the register. Magnetic drive units are now available, and older mechanical drive meters can be updated and converted to magnetic drive units. The newer meters use magnetic couplings to drive the registers which eliminates many mechanical parts. The mechanically driven register has a number of disadvantages in that it has more moving parts, fogs up when set in the ground and corrodes. Magnetically driven registers are better protected, being normally hermetically-sealed (air tight) and somewhat tamper-proof. The magnetic drive gets rid of the conventional stuffing box to greatly reduce the friction in the mechanism.

The total flow measured by meters may be read directly from the registers on the meters or may be read remotely. The flow rate can be read from gages, either indicating or recording, which can be mounted at any convenient location. Stirp chart or circular chart recorders may be used to provide continuous permanent records. Metering operations can become quite complex. Customer meter readings can be converted into electrical data, transmitted by telemetry via telephone lines from the meter to a central utility office, where they are translated by a data processor or recording device that compiles the meter-reading information. The compiled readings may then be transferred manually or automatically to the billing office for further manipulation.

Service meters may be installed and read either indoors or outdoors. Indoor locations are often used in cold weather areas; however, they can present a problem of access to the meter reader and can be an annoyance to the owner or resident. This has led to the use of remote-reading registers which are installed on the same premise as the meter. They are located where they can be easily observed. With this type of operation, the time required to read meters has been greatly reduced. Remote reading meters are becoming more popular.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.73A A meter testing program should be based on what facts?

5.73B What types of water meter is usually maintained and repaired by the utility?

5.73C How are meter registers driven?

5.734 Maintenance

Like any other mechanical device, meters need regular servicing to maintain their efficiency. Their many moving parts and bearing surfaces always eventually result in some degree of wear. Wear, corrosion, and deposition result in inaccurate registration. Over-registration rarely occurs. Instead, the usual result of meter deterioration is under-registration which is of serious concern because it results in a loss of revenue.

Some water should be sealed in a meter when a meter is taken out of service in the field. This can be done with slip-in plugs or protective caps which will also protect the threads on the connections. Do not allow the inside of a meter to dry out or allow anything to get inside the meter because either situation can change the way a meter measures water flow. An electrical jumper should be installed around a meter whenever working on a meter to protect you from electrical shock.

Meter maintenance and repair consists essentially of dismantling and thoroughly cleaning the meter and inspecting all of its parts. The step-by-step procedures used for a nutating disc meter are:

1. Remove meter from service and take to shop,
2. Test meter for accuracy,
3. Dismantle the meter,
4. Inspect the various parts for excessive wear and corrosion, pitting, or distortion,
5. Replace all defective and badly worn parts,
6. Thoroughly clean all parts to be used,
7. Assure that the gear train (if any) runs freely,
8. Check action of the disc in the chamber of the main casing before and after assembly,
9. Use a new meter as a comparison standard for tolerances and clearances, and
10. Retest the meter for accuracy.

The cost of meter maintenance, especially for large meters, can be quite small compared to the revenues that would be gained in the long term. Each utility should select the best method of meter maintenance for its own situation, determine the most economical test frequency, and stick to their planned program.

5.735 Meter Reading

Every operator who may have to read a meter should have a thorough understanding of how to do it correctly. The customer should be paying a fair bill for the amount of water being used. Also, the customer may be able to read the meter and the operator had better be correct if questioned. An alert meter reader can often spot under-registering of meters by a quick comparison with past readings. Meter stoppages should be noted immediately at the time of the meter reading and reported.

Figure 5.44 shows a water meter with circular register face. As shown on the face, the meter records in cubic feet. In reading a meter of this type, start with the scale showing the highest number (10,000,000) and then read each scale around the register successively until the lower numbered scale (10) is read. Note that in some scales the hands go in a

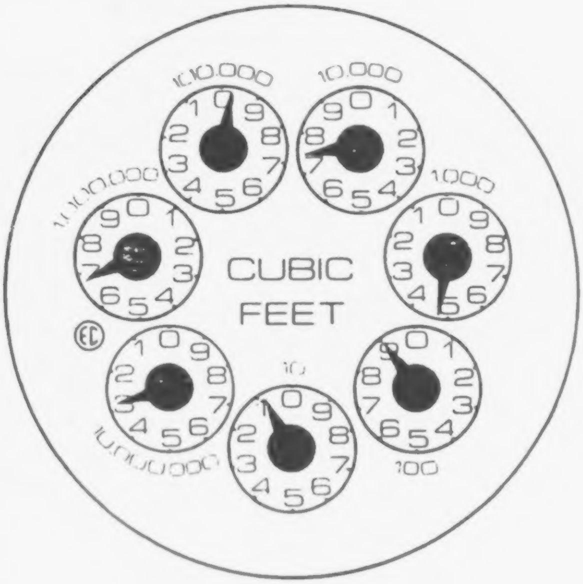


Fig. 5.44 Water meter

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

clockwise direction, while in others they move counterclockwise. If a hand is between two numbers, the lower number is used. If the hand is close to a number, the hand on the next scale should be looked at to see if it is past the zero (0) point. If that hand is not on or past zero (0), the hand being read is still between the two numbers and the lower number on the dial should be read. If it is on or past zero (0), the higher number is used.

When a hand makes a complete revolution on its dial, the amount of water that has passed through the meter equals the number designated above that dial. One revolution on the 10 dial is 10 cubic feet and one revolution on the 10,000,000 dial is 10 million cubic feet. For the 10 dial, the numbers correspond to 1 through 9 cubic feet; and for the 10,000,000 dial, the numbers are 1 million through 9 million cubic feet. Other meters might read in gallons or in metric units depending on what is shown on the face. Some meters have multipliers shown on the meter or the dial face such as "10X" or "100X." To determine the correct total, the reading must be multiplied by the multiplier.

The most important consideration in getting an accurate reading is that the proper number of digits be determined. As a check, the final meter reading should be between the numbers shown on the largest numbered scale read and the next largest. An error in the higher numbered scales will be much more significant than one in the lower numbered scales. Never make the assumption that the previous reading was correct.

Many meters have digital readouts. This means that you merely read and record the numbers shown by the meter. Figure 8.45 is a digital readout totalizing water meter.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 277.

5.73D What causes inaccurate meter registration?

5.73E List the procedures used for meter maintenance and repair.

5.73F What is the meter reading for the meter shown in Figure 5.44?

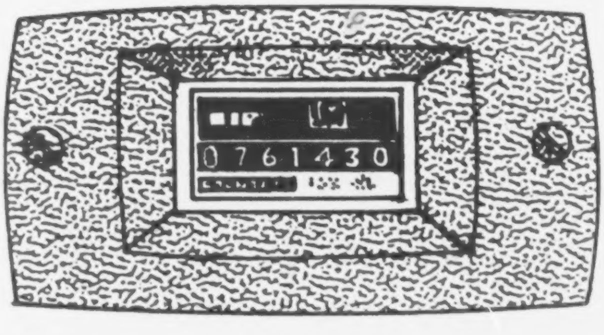
5.74 Main Breaks

Breaks in water mains can occur at any time and every agency must have an established, written response plan. A break may be obvious, such as water spouting from a main as a result of a traffic accident, an earthquake or a washout. At other times, consumers may complain of a lack of pressure or no water at all and the underground break will have to be located.

Sometimes a main will fail under the middle of a paved street and water will be flowing out from under the outside edges of the pavement. When this happens, locate the section of broken main in the center of the pavement. Poke holes through the pavement over the main until the point where the greatest water discharge is located. Don't do any poking in areas where underground electrical or other types of cables may be buried.

After a break has been located, determine which valves will have to be closed to isolate the break. A good policy *BEFORE* shutting off any valves is to notify every consumer involved that they will be out of water for an estimated length of time. The purpose of this advance notification is to allow consumers to make any necessary preparations. For example, water-cooled refrigeration equipment must be shut off before the valves are closed. If extensive damage is being caused by the break (flooding and/or washouts), you will have to close the valves and isolate the section as soon as possible and maybe even before notifying all consumers.

After the valves are closed, a trash pump can be used to drain the hole. A backhoe or other equipment can be used to dig down to the break. Before anyone enters the hole, determine the necessary shoring needs. Use the appropriate shoring (see Section 3.653, "Excavation and Shoring" in Chapter 3). Remove the damaged section of pipe. Remove as much silt and debris as possible from the remaining sections of the main by flushing or other methods. Replace the damaged section of pipe and/or valves using clamps and other fittings. Flush the entire section which was isolated using hydrants or drains. Disinfect the system by following the procedures for disinfecting mains as outlined in Section 5.8, "Field Disinfection." Figure 5.46 is a "Water Main Failure Report" used by some agencies to evaluate the cause of breaks and to justify preventive measures.



Totalizing receiver

Fig. 5.45 Digital readout totalizing water meter

NO.____________

WATER MAIN FAILURE REPORT
FIELD DATA FOR MAIN BREAK EVALUATION

DATE OF BREAK____________ TIME: ____________ A.M.____________ P.M.

TYPE OF MAIN:____________ SIZE________ JOINT____________ COVER____ FT.____ IN.

THICKNESS AT POINT OF FAILURE____________ INCH.

NATURE OF BREAK: Circumferential ☐ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐

Split at Corporation ☐ Sleeve ☐ Miscellaneous____________ (describe) ☐

APPARENT CAUSE OF BREAK: Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐

Improper Bedding ☐ Excessive Operating Pressure ☐ Differential Settlement ☐ Temp Change ☐ Contractor ☐ Misc.________ (describe) ☐

STREET SURFACE: Paved ☐ Unpaved ☐ TRAFFIC: Heavy ☐ Medium ☐ Light ☐

TYPE OF STREET SURFACE____________ SIDE OF STREET: Sunny ☐ Shady ☐

TYPE OF SOIL____________ RESISTIVITY ____________ohm/cm

ELECTROLYSIS INDICATED: Yes ☐ No ☐ CORROSION: Outside ☐ Inside ☐

CONDITIONS FOUND: Rocks ☐ Voids ☐ PROXIMITY TO OTHER UTILITIES____________

DEPTH OF FROST ________ INCH DEPTH OF SNOW________ INCH

OFFICE DATA FOR MAIN EVALUATION

WEATHER CONDITIONS: PREVIOUS TWO WEEKS____________

SUDDEN CHANGE IN AIR TEMP? Yes ☐ No ☐ TEMP.________°F. RISE________°F. FALL________°F.

WATER TEMP.: SUDDEN CHANGE: Yes ☐ No ☐ TEMP.________°F. RISE________°F. FALL________°F.

SPEC. OF MAIN____________ CLASS OR THICKNESS____________ LAYING LENGTH____________ FT.

DATE LAID____________OPERATING PRESSURE____________PSI. PREVIOUS BREAK REPORTED____________

INITIAL INSTALLATION DATA:

TRENCH PREPARATION: Native Material____________ (describe type) ☐ Sand Bedding ☐ Gravel Bedding ☐

BACKFILL: Native Material ☐ DESCRIBE____________ Bank Run Sand & Gravel ☐

Gravel ☐ Sand ☐ Crushed Rock ☐ OTHER____________

SETTLEMENT: Natural ☐ Water ☐ Compactors ☐ Vibrators ☐ OTHER____________ (describe)

ADDITIONAL DATA FOR LOCAL UTILITY USE

LOCATION OF BREAK____________ MAP NO.____________

REPORTED BY____________

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY____________

____

REPAIRS MADE (Materials, Labor, Equipment)____________

____

REPAIR DIFFICULTIES (If Any)____________

____

INSTALLING CONTRACTOR____________

Fig. 5.46 Water main failure report

5.75 Corrosion Control

Whenever water mains are drained for any reason they should be inspected for signs of corrosion. Also pieces of pipe removed during tapping operations or sections of pipe removed for repair or replacement should be examined for indications of corrosion.

Some agencies insert *COUPONS*[17] (Figure 5.47) in water mains to serve as an indication of the corrosiveness of water and the rate of corrosion of the water mains. The rate of corrosion is measured by the loss of weight of the coupon between weighing time intervals. Be sure to scrape off all encrustations before weighing the coupons.

Another indication of corrosion problems is when consumers complain of red water. By marking on a map the location of consumer complaints, you can identify those water mains where the corrosion problem is the most serious.

There are numerous ways to control corrosion and frequently several methods may be used at the same time. Chemicals can be added to water at a treatment plant to help control the corrosion of water mains. Water mains can be lined with protective coatings to control corrosion (see Section 5.708, "Lining"). Cathodic protection is the use of an electrical system to prevent corrosion.

Water mains must be protected from both internal corrosion and external corrosion. For detailed procedures on how to control corrosion, see Section 3.64 "Pipe Protection," and Chapter 8, "Corrosion Control," in *WATER TREATMENT PLANT OPERATION*, Volume 1, of this series of manuals.

QUESTIONS

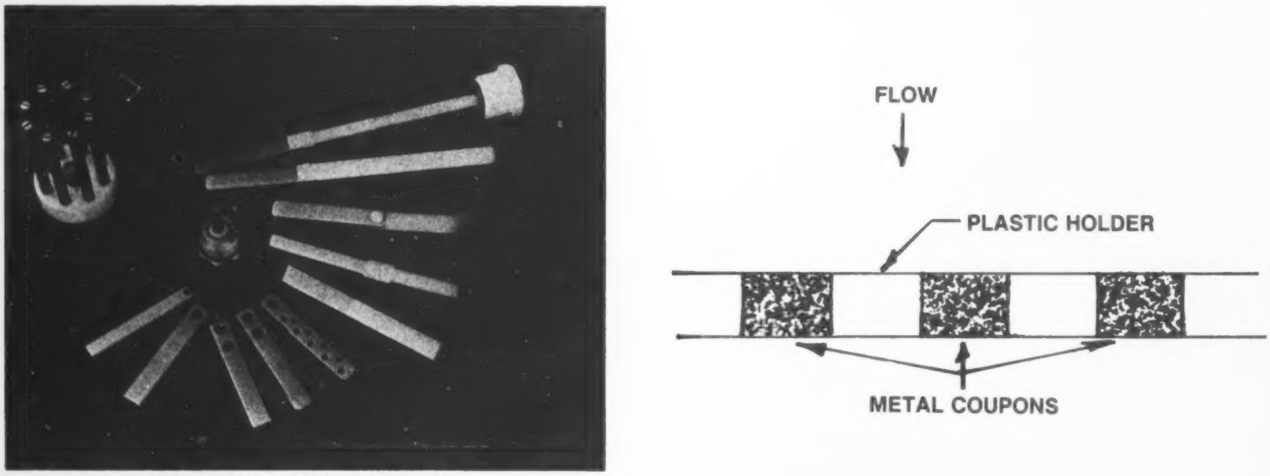
Write your answers in a notebook and then compare your answers with those on page 277.

5.74A List the possible causes of a water main break.

5.74B How can the hole where a water main break is located be drained?

5.75A Why are coupons installed in water mains?

End of Lesson 3 of 4 Lessons
on
DISTRIBUTION SYSTEM OPERATION and MAINTENANCE



Pipe plug assembly coupons
(Permission of Metal Samples Co., Inc.)

Fig. 5.47 Coupon

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 3 of 4 Lessons)

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

19. Why are valves installed in distribution systems?
20. How can frozen fire hydrants be thawed?
21. How would you determine the frequency of a meter testing program?
22. What are the limitations of mechanically driven meters?

---

[17] *Coupon. A steel specimen inserted into water to measure the corrosiveness of water. The rate of corrosion is measured as the loss of weight of the coupon (in milligrams) per surface area (in square decimeters) exposed to the water per day.*
10 decimeters = 1 meter = 100 centimeters

CHAPTER 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 4 of 4 Lessons)

5.8 FIELD DISINFECTION

5.80 Need for Disinfection

Field disinfection of distribution system mains and reservoirs is necessary when they are new, after repairs are made, or whenever there is any possibility of contamination. Under any of these conditions, inadequate disinfection could result in a waterborne-disease outbreak somewhere in the community with your utility agency being legally liable.

5.81 Disinfection of Mains[18]

During the construction of a new water line, or after an extensive repair (involving dewatering), there is a small but real opportunity for contamination of the line even if special precautions as described in Chapter 3 have been taken. Therefore, effective disinfection is necessary before the line is placed into service.

The disinfecting agent most often used is chlorine which is available in three chemical forms:

1. Liquid chlorine contains 100 percent available chlorine and is packaged in 100 pound, 150 pound, or one ton (45, 68, or 909 kg) steel cylinders. Special equipment and controls, trained operators, and close attention to safety practices are needed when chlorine gas is used.
2. Sodium hypochlorite is a liquid solution. This form of chlorine contains approximately 5 to 15 percent available chlorine and comes in one-quart to five-gallon (1.0 to 20 liters) containers. Precautions must be taken to prevent deterioration of the hypochlorite solution. Store hypochlorite in a cool, dark location and use as soon as possible.
3. Calcium hypochlorite is available as a dry material, of approximately 65 percent as available chlorine and comes in powder, granular, or tablet form. Calcium hypochlorite is relatively soluble in water and, therefore, adaptable to solution feeding. Storage conditions must be controlled to prevent deterioration or reaction with combustible chemicals or materials.

Disinfection is commonly accomplished using the tablet, continuous feed or slug methods, depending on the type of chlorine used and specific job conditions.

Tablets are best suited for short sections (a few hundred feet) and small-diameter lines [24 inches (600 mm) or less]. Since preliminary flushing cannot be performed, tablets cannot be used unless the main is initially kept clean and dry. As the pipe is laid in the trench, tablets are placed in each pipe section by securely attaching them by an approved adhesive to the top of the pipe. Sufficient tablets are added to provide a dose of 25-50 mg/*L* chlorine (see Table 5.2). The line is filled slowly [less than one foot (0.3 m) of pipe per second] to prevent the tablets being flushed away. The chlorinated water is allowed to remain in the line for at least 24 hours. Check the chlorine residual during the test to be sure the residual does not drop below 25 mg/*L*. Sometimes the tablets will be washed to the far end of the pipe when the pipe is being filled with water. For this reason, samples should be collected from the entire length of pipe and the chlorine residual measured to be sure the chlorine is uniformly distributed through out the pipe.

TABLE 5.2 PIPE DISINFECTION USING TABLETS[a]

Pipe Diameter, in	Number of Five-gram Hypochlorite Tablets Required for a Dose of 25 mg/*L*				
	Length of Pipe Section, ft				
	13 or less	18	20	30	40
4	1	1	1	1	1
6	1	1	1	2	2
8	1	2	2	3	4
10	2	3	3	4	5
12	3	4	4	6	7
16	4	6	7	10	13

[a] AWWA Standard for Disinfecting Water Mains, ANSI/AWWA C601-81.

[b] Based on 3.25 grams available chlorine per tablet, any portion of tablet required rounded to next higher number.

In the continuous-feed method, preliminary flushing at not less than 5 ft/sec (1.5 m/sec) is required. A chlorine solution containing not less than 25 mg/*L* free chlorine is injected into the pipe through a corporation cock or other fitting. The solution is infected as the line is being filled. Table 5.3 gives the amount of chlorine required for each 100 feet (30 m) of pipe of various diameters. At the end of a minimum 24-hour period, properly treated water will have a residual of not less than 10 mg/*L* free chlorine in all portions of the main.

TABLE 5.3 CHLORINE REQUIRED TO PRODUCE 25 mg/*L* CONCENTRATION IN 100 FEET OF PIPE[a]

Pipe Diameter, in	100 Percent Chlorine, lb	1 Percent Chlorine Solutions, gal
4	0.013	0.16
6	0.030	0.36
8	0.054	0.65
10	0.085	1.02
12	0.120	1.44
16	0.217	2.60

[a] AWWA Standard for Disinfecting Water Mains, ANSI/AWWA C601-81.

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[18] *AWWA STANDARD FOR DISINFECTING WATER MAINS, C601-81. Obtain from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235. Order No. 43601; price to members, $7.00, nonmembers; $8.50.*

The slug method is especially advantageous for use with long, large-diameter mains as it reduces the volume of heavily chlorinated water to be flushed to waste and results in significant savings in chlorine costs. Place calcium hypochlorite (granules or tablets) in the main during construction in quantities shown in Table 5.4. This initial chlorine dose will meet the initial chlorine demand. Fill the main completely to remove all air pockets; then flush.

TABLE 5.4 PIPE DISINFECTION USING GRANUALS[a]

Pipe Diameter, in	Ounces of Calcium Hypochlorite Granules to be Placed at Beginning of Main and at Each 500-ft Interval Calcium Hypochlorite Granules, oz
4	0.5
6	1.0
8	2.0
12	4.8
16 and larger	8.0

[a] AWWA Standard for Disinfecting Water Mains, ANSI/AWWA C601-81.

Next, using the continuous feed method, dose the water to produce and maintain a chlorine concentration of at least 100 mg/*L* free chlorine. Apply the chlorine continuously for a long enough time period to produce a slug of highly chlorinated water that will move through the main and expose all interior surfaces of the main to a chlorine concentration of 100 mg/*L* as it is being applied and in the main as the slug moves along.

If the free chlorine residual in the slug drops below 50 mg/*L*, stop the flow, add more chlorine to the slug to increase the residual to 100 mg/*L* and continue. Try to maintain the three hour contact time. When the chlorine slug flows past fittings and valves, operate related valves and hydrants in order to disinfect pipe branches and appurtenances.

After the slug has passed through the main, flush out the chlorinated water until the chlorine concentration in the water leaving the main is no higher than that commonly found in the system. When the disinfection procedures are completed, collect bacteriological samples. Do not put the main into service until the samples are found to be negative for coliform organisms. If positive coliform samples are found, reflush the main and resample. If samples are still positive, the main must be rechlorinated and resampled until satisfactory results are obtained. The 24-hour membrane filter test is commonly used to test for coliform bacteria to expedite results.

Repair of mains under pressure presents little danger of contamination and disinfection is not required. However, when mains are wholly or partially dewatered, they must be disinfected. In wet excavations, large quantities of hypochlorite are applied to open trench areas to lessen the danger of contamination. The interior of all pipes and fittings used in making the repair must be swabbed or sprayed with a one percent hypochlorite solution before they are installed.

The most practical way of removing contamination introduced during repairs is by thorough flushing. Where it can be done, a section of main in which the break is located should be isolated and all service connections shut off. Then the section should be flushed and chlorinated using the slug method as described for new main disinfection except that the dose may be increased to as much as 300 mg/*L* and the contact time reduced to as little as 15 minutes.

After the chlorination has been completed, flushing is resumed and continued until any discolored water is eliminated and the water is free of noticeable chlorine odor. The main may be returned to service prior to completion of bacteriological testing so that the time customers are out of water will be minimized. Samples should be taken on each side of the main break if the direction of flow is not known. If positive samples are found, daily sampling must be continued until two consecutive samples are negative.

For more details on the disinfection of water mains, see Chapter 6, "Disinfection."

FORMULAS

To determine the flow in a pipe in gallons per minute, we usually have to calculate the flow in cubic feet per second. The flow in cubic feet per second (CFS) is determined by multiplying the area of the pipe in square feet times the velocity. We have referred to this formula as $Q = AV$.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

We divided by 144 sq in/sq ft to convert the calculated area from square inches to square feet.

$$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

or

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

EXAMPLE 8

A 6-inch diameter water main is to be flushed at 4 ft/sec before disinfection. What should be the reading on the flow meter in gallons per minute?

Known		Unknown
Diameter, in	= 6 in	Flow, GPM
Velocity, ft/sec	= 4 ft/sec	

1. Calculate the flow in cubic feet per second.

$$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= \frac{(0.785)(6 \text{ in})^2(4 \text{ ft/sec})}{(144 \text{ sq in/sq ft})}$$

$$= 0.785 \text{ cu ft/sec}$$

2. Convert flow in cubic feet per second to GPM.

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= (0.785 \text{ cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= 352 \text{ gal/min}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.8A Why should distribution system mains and reservoirs be disinfected?

5.8B List three forms of chlorine available for disinfecting a water main.

5.8C When using tablets to disinfect a water main, how long should the chlorinated water remain in the line?

5.8D What should be done when the disinfection procedures for a water main are completed?

5.82 Disinfection of Storage Facilities

A detailed description of procedures to disinfect storage facilities is given in AWWA D105-80, *"AWWA STANDARD FOR DISINFECTION OF WATER STORAGE FACILITIES"*[19] and in Chapter 6, "Disinfection." If the water agency contracts out this work, the contract should specify use of the appropriate AWWA standard.

Distribution system storage facilities must be disinfected when they are newly installed before being placed in or returned to service or when they are taken out of service (dewatered) for any reason and whenever the possibility exists that the water has become contaminated.

Before disinfection is started, cleaning of the facilities is necessary. All materials not belonging in the empty tank must first be removed. Then, all interior surfaces of the facility are cleaned thoroughly using a high pressure water jet, scrubbing, sweeping, or some equivalent method. Water and dirt that have accumulated from the cleaning operation are discharged or otherwise removed before disinfection starts.

TABLE 5.5 AMOUNTS OF CHEMICALS REQUIRED TO GIVE VARIOUS CHLORINE CONCENTRATIONS IN 100,000 GALLONS OF WATER[a]

Desired[b] Chlorine Dose in Water, mg/L	Pounds of Liquid Chlorine Required	Gallons of Sodium Hypochlorite Required			Pounds of Calcium Hypochlorite Required
		5% Available Chlorine	10% Available Chlorine	15% Available Chlorine	65% Available Chlorine
2	1.7	3.9	2.0	1.3	2.6
10	8.3	19.4	9.9	6.7	12.8
50	42.0	97.0	49.6	33.4	64.0

[a] From AWWA Standard D105-80, *DISINFECTION OF WATER STORAGE FACILITIES.*

[b] Amounts of chemicals are for initial concentrations of available chlorine. Allowance may need to be made for chlorine depletion where low concentrations are held for extended time perids.

The same forms of chlorine used for main disinfection can be used for disinfecting storage facilities. These are liquid chlorine, sodium hypochlorite solution, and calcium hypochlorite solution, and calcium hypochlorite granules or tablets. Table 5.5 shows the amounts of chemicals required to provide various initial chlorine concentrations in 100,000 gallons of water.

Three methods of chlorination are described in the AWWA standard shown in Table 5.5 The operator should decide which of these methods is most suitable considering the availability of materials and equipment, training status of the operators who will do the disinfection, and safety considerations.

In Chlorination Method 1 of the AWWA Standard, the storage facility is filled to the overflow level with potable water and enough chlorine is added to provide a free chlorine residual in the full facility of not less than 10 mg/*L* at the end of the required retention period. When chlorine gas is used, the water entering the storage facility is chlorinated uniformly by a chlorinator. If sodium hypochlorite is used, it is poured into the storage facility as it begins filling, when the depth of the water is between 1 and 3 feet (0.3 and 1 m). If calcium hypochlorite is used, granules or tablets are poured into or placed in the storage facility before water is discharged into it. If chlorine gas is used, the required retention period is not less than six hours. When sodium hypochlorite or calcium hypochlorite is used, a minimum (chlorine contact) period of 24 hours is required. After the required retention period, the free chlorine residual in the water is reduced to not more than 2 mg/*L* to minimize possible complaints when the water is served. This can be done by completely draining and refilling the facility, or by additional holding time, and/or by blending the potable water having a low chlorine concentration.

In Chlorination Method 2, the surfaces of all parts of the storage facility which would be in contact with the water are thoroughly coated with a solution of 200 mg/*L* free available chlorine using brushes or spray equipment. Potable water is used to fill the reservoir after at least 30 minutes of contact time after application of the chlorine solution.

In Chlorination Method 3, the storage facility is filled to approximately five percent of the total storage volume. Sufficient chlorine is then added to provide a 50 mg/*L* available chlorine solution which is held for a period of not less than six hours. The facility is then filled to the overflow level and the chlorinated water is held for at least 24 hours. At the end of the 24-hour holding period, there must be a minimum of two mg/*L* free chlorine residual.

In all cases; water is not delivered to the distribution system until bacteriological tests are negative for coliform organisms and the water is of acceptable aesthetic quality. The 24-hour membrane filter test for coliform is commonly used in this case because results are available quicker than the multiple fermentation tube (MPN) method. If coliform bacteria are found, repeat samples must be taken until two consecutive samples are negative. The water should also be tested to be certain there is no offensive odor or color.

If the chlorinated water is discharged to the environment and there is a possibility it may be toxic to fish and other aquatic life, the chlorine residual must be neutralized using a reducing agent. Also chlorinated water should not be discharged to a sewer if there is any possibility of a chlorine residual remaining in the wastewater when it reaches a treatment plant. Table 5.6 shows the amounts of reducing chemicals required to neutralize various residual chlorine concentrations in 100,000 gallons of water. Disposal of highly chlorinated water may require a permit from a regulatory agency.

For additional detailed procedures on now to disinfect storage facilities, see Chapter 6, "Disinfection."

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[19] *Obtain from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235. Order No. 44105; price to members $5.00; nonmembers $6.40.*

Table 5.6 AMOUNTS OF CHEMICALS REQUIRED TO NEUTRALIZE VARIOUS RESIDUAL CHLORINE CONCENTRATIONS IN 100,000 GALLONS OF WATER[a]

Residual Chlorine Concentration mg/*L*	Pounds of Chemical Required			
	Sulfur Dioxide (SO_2)	Sodium Bisulfite ($NaHSO_3$)	Sodium Sulfite (Na_2SO_3)	Sodium Thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$)
1	0.8	1.2	1.4	1.2
2	1.7	2.5	2.9	2.4
10	8.3	12.5	14.6	12.0
50	41.7	62.6	73.0	60.0

[a] From AWWA Standard D105-80, *DISINFECTION OF WATER STORAGE FACILITIES.*

FORMULAS

When disinfecting either a water main or a storage facility, we need to know the volume to be disinfected in million gallons and desired chlorine dose in milligrams per liter.

$$\text{Chlorine Needed, lbs} = (\text{Volume, M Gal})(\text{Chlorine Dose, mg}/L)(8.34\ \text{lbs/gal})$$

If a hypochlorite solution is used to provide the chlorine needed, we need to know the percent of chlorine in the hypochlorite solution to calculate the gallons of hypochlorite required.

$$\text{Chlorine Needed, lbs} = \frac{(\text{Hypochlorite, gal})(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}{100\%}$$

or

$$\text{Hypochlorite, gal} = \frac{(\text{Chlorine Needed, lbs})\ (100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}$$

EXAMPLE 9

A 50,000-gallon storage tank is to be disinfected with a chlorine solution of 50 mg/*L*. How many pounds of chlorine (gas) will be needed?

Known		Unknown
Tank Volume, gal	= 50,000 gal	Chlorine Needed, lbs
Million, gal	= 0.050 M gal	
Chlorine Conc., mg/*L*	= 50 mg/*L*	

Formula for calculating pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Tank Volume, M Gal})(\text{Chlorine, mg}/L)(8.34\ \text{lbs/gal})$$

Calculate the pounds of chlorine needed.

$$\begin{aligned}\text{Chlorine, lbs} &= (\text{Tank Volume, M Gal})(\text{Chlorine, mg}/L)(8.34\ \text{lbs/gal})\\ &= (0.050\ \text{M Gal})(50\ \text{mg}/L)(8.34\ \text{lbs/gal})\\ &= 21\ \text{lbs}\end{aligned}$$

EXAMPLE 10

How many gallons of five percent hypochlorite solution will be needed to disinfect the storage tank in Example 9 (where 21 pounds of chlorine gas was needed)?

Known		Unknown
Chlorine Needed, lbs	= 21 lbs	Hypochlorite, gallons
Hypochlorite, %	= 5%	

Formula for calculating pounds of available chlorine.

$$\text{Chlorine, lbs} = (\text{Hypochlorite, gal})(8.34\ \text{lbs/gal})\left(\frac{\text{Hypochlorite, \%}}{100\%}\right)$$

Calculate gallons of hypochlorite needed.

$$\begin{aligned}\text{Hypochlorite, gal} &= \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}\\ &= \frac{(21\ \text{lbs})(100\%)}{(8.34\ \text{lbs/gal})(5\%)}\\ &= 50\ \text{gallons}\end{aligned}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.8E When should distribution system storage facilities be disinfected?

5.8F How can the interior surfaces of a storage facility be cleaned before disinfection?

5.8G After the required retention (chlorine contact) period for disinfecting a storage facility is over, how is the free chlorine residual in the water reduced to less than 2 mg/*L*?

5.8H List the reducing agents that could be used to neutralize a free chlorine residual in water that has been used to disinfect a storage facility.

5.9 Records

5.90 Importance of Records

In too many systems the importance and value of keeping good records are not recognized. Where this occurs, the operators may not know (or be able to find) the construction details of important facilities, where they are located, or what shape they are in. The need for a good record system regardless of the size or complexity of the water system cannot be overemphasized.

Records are needed for many reasons. In general, they promote the efficient operation of the water system. Records can remind the operator when routine operation or maintenance is necessary and help assure that schedules will be maintained and no needed operation or maintenance will be overlooked or forgotten. Records are the key to an effective maintenance program. They are also needed for those regulatory agencies which require submission of periodic water quality and operational records. Records can be used to determine the financial health of the utility, provide the basic data on the system's property, and in preparing monthly and annual reports. Another reason for keeping accurate and complete records of system operations is the legal liability of the utility. Such records are required as evidence of what actually occurred in the system. Good records can help when threatened with litigation. Records also assist in answering consumer questions or complaints. Finally, clear, concise records are required to effectively meet future operational needs, that is for planning purposes.

Records should be tailored to meet the demands of the particular system and only records known to be useful should be kept. Operators should determine what type of information will be of value for their system and then prepare maps, forms, or other types of records on which the needed information can be easily recorded and clearly shown. Records should be prepared as if they will be kept indefinitely. In fact some will be kept for a long time, while other records will not. Records should be put into a filing system that can be easily used and understood by everyone concerned, readily accessible and protected from damage in a safe environment. The non-permanent records should be disposed of in accordance with a disposal schedule set up for the different types of records maintained. Good record-keeping tips can be found throughout these manuals.

5.91 Maps

Comprehensive maps and sectional plats are used by most utilities. The comprehensive map provides an overall view of the entire distribution system. Important structures are shown, including water intakes, treatment plants, wells, reservoirs, mains, hydrants and valves. The preferred scale for comprehensive maps is 500 feet per inch, while the maximum scale recommended is 1,000 feet per inch. Sectional plats will show various portions of the comprehensive map in much more detail (Figure 8.48). The scale varies from 50 to 200 feet per inch. Standard symbols are used to indicate different items on these and other utility maps. Some common symbols are shown in Figure 5.49.

Valve the hydrant maps as shown in Figure 5.50 may cover the same area as up to four sectional maps. They not only show valve and hydrant locations, but provide such information as the direction to open the valve, the number of turns to open, the model type and the installation date. A valve intersection plat with the valves identified by letters is shown in Figure 5.51.

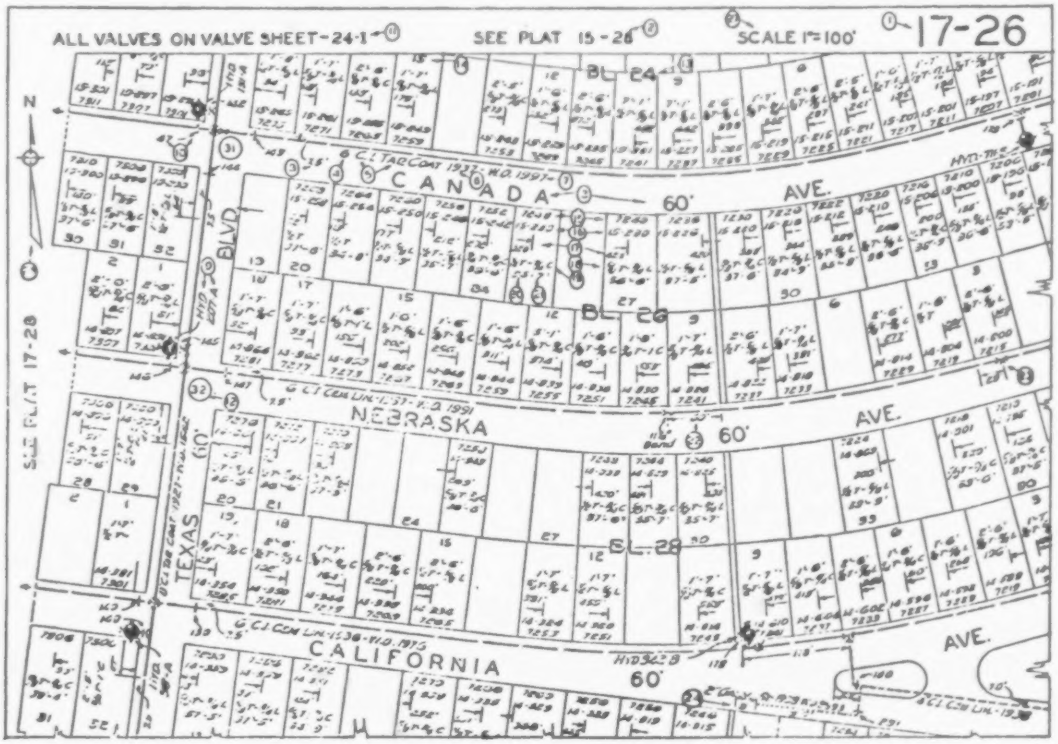

Fig. 5.48 Portion of sectional plat

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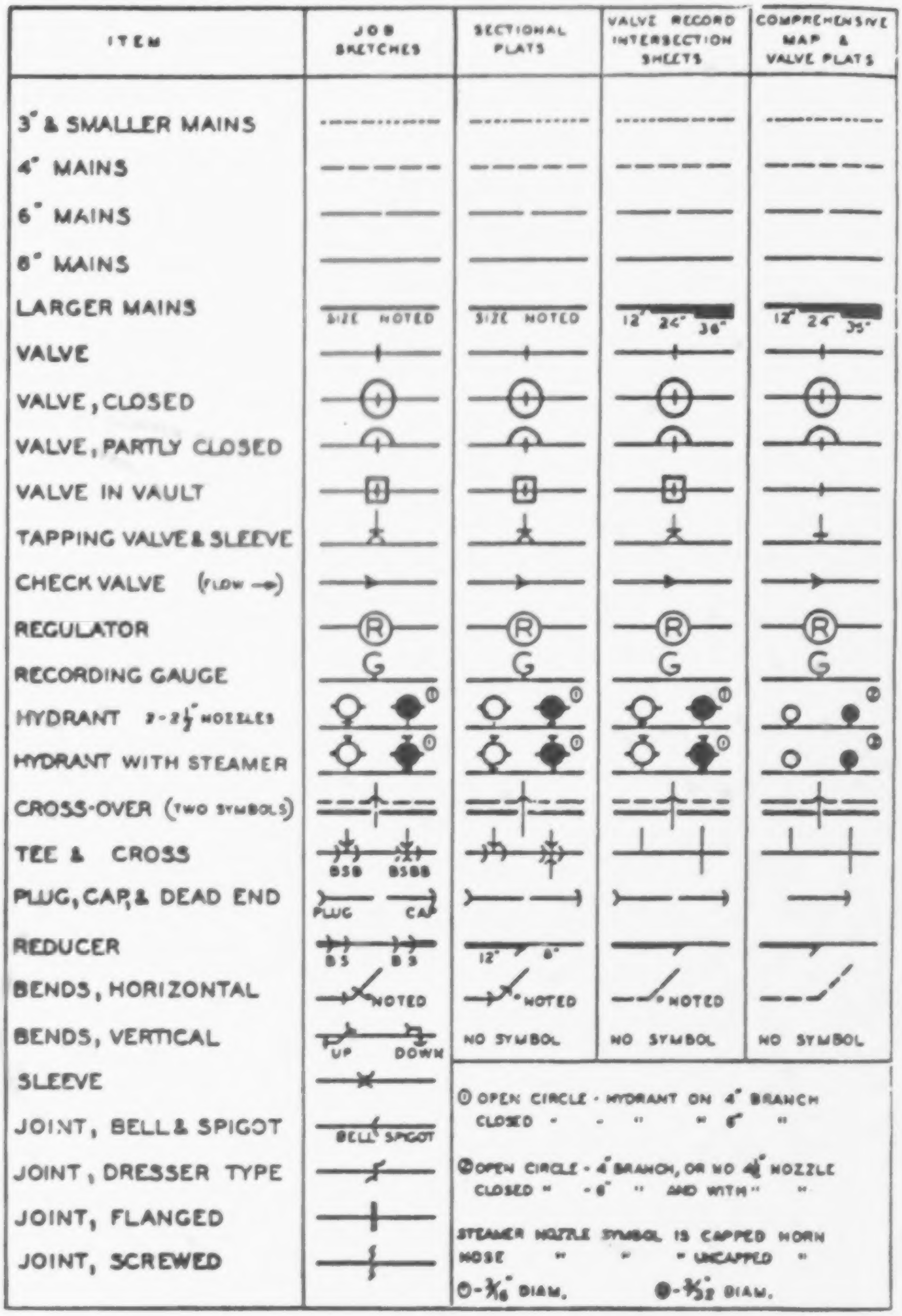

ITEM
JOB SKETCHES
SECTIONAL PLATS
VALVE RECORD INTERSECTION SHEETS
COMPREHENSIVE MAP & VALVE PLATS
3" & SMALLER MAINS
4" MAINS
6" MAINS
8" MAINS
LARGER MAINS
SIZE NOTED
12" 24" 36"
VALVE
VALVE, CLOSED
VALVE, PARTLY CLOSED
VALVE IN VAULT
TAPPING VALVE & SLEEVE
CHECK VALVE (FLOW →)
REGULATOR
R
RECORDING GAUGE
G
HYDRANT 2-2½" NOZZLES
HYDRANT WITH STEAMER
CROSS-OVER (TWO SYMBOLS)
TEE & CROSS
BSB
BSBB
PLUG, CAP, & DEAD END
PLUG
CAP
REDUCER
BS
12"
8"
BENDS, HORIZONTAL
NOTED
BENDS, VERTICAL
UP
DOWN
NO SYMBOL
SLEEVE
JOINT, BELL & SPIGOT
BELL
SPIGOT
JOINT, DRESSER TYPE
JOINT, FLANGED
JOINT, SCREWED
① OPEN CIRCLE - HYDRANT ON 4" BRANCH
CLOSED " - " " 6" "
② OPEN CIRCLE - 4" BRANCH, OR NO 4½" NOZZLE
CLOSED " - 6" " AND WITH " "
STEAMER NOZZLE SYMBOL IS CAPPED HORN
NOSE " " " UNCAPPED "
○-3/16" DIAM.
●-5/32" DIAM.

Fig. 5.49 Common map symbols

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

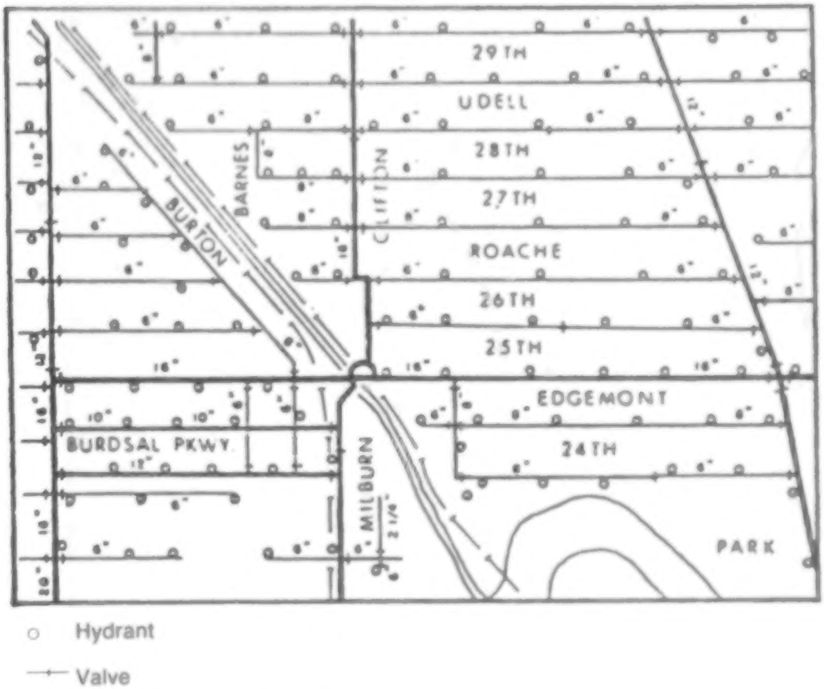

29TH
UDELL
28TH
27TH
ROACHE
26TH
25TH
EDGEMONT
24TH
BURTON
BARNES
CLIFTON
BURDSAL PKWY.
MILBURN
PARK
○ Hydrant
Valve

Fig. 5.50 Valve and hydrant map

(Reprinted from *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*, by permission. Copyright 1976, the American Water Works Association)

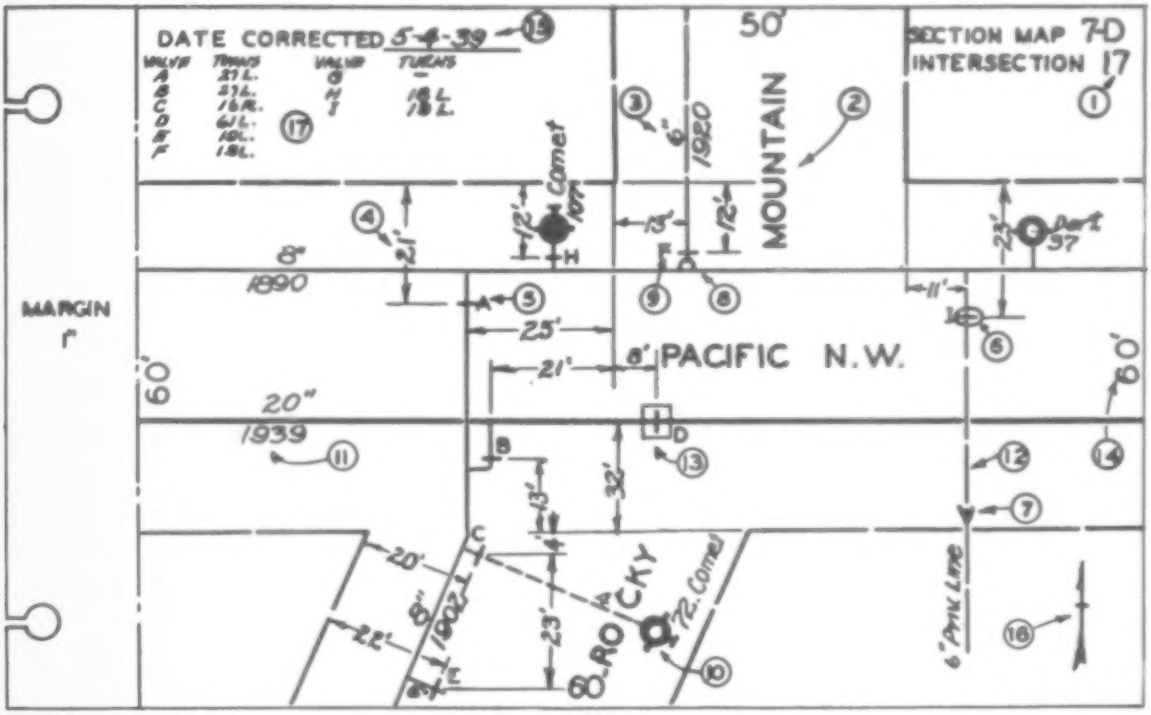

DATE CORRECTED 5-4-39
VALVE TURNS VALVE TURNS
A 27L. G —
B 27L. H 18L
C 16R. I 18L.
D 6L.
E 10L.
F 18L.
SECTION MAP 7-D
INTERSECTION 17
MARGIN 1"
50'
MOUNTAIN
1920
6"
Comet 1077
8"
1890
PACIFIC N.W.
20"
1939
60'
ROCKY
72. Comet
8"
1902
6" Prv. Line
Art 57
21'
12'
15'
25'
21'
8'
11'
23'
32'
13'
20'
22'
23'
60

Fig 5.51 Valve intersection plat

(Reprinted from *WATER DISTRIBUTION TRAINING COURSE*, by permission. Copyright 1962, the American Water Works Association)

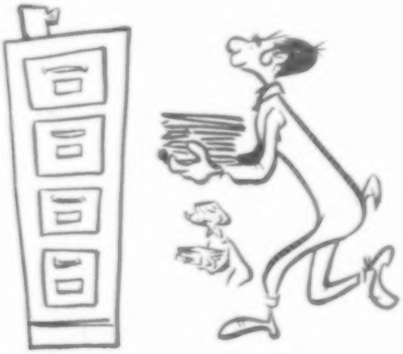
Other types of maps are also used. Leak survey maps are usually another modification of sectional or valve maps and, where regular leak survey work is conducted, these maps show the valves to be closed and the areas to be isolated. Leak frequency maps show the locations where leaks have been found and pinpoint problem areas. Customer complaints, when indicated on a map, are also very helpful in showing problem areas and the need for follow-up investigations. Locations of leaks and complaints may be marked on wall-mounted maps by pins with colored heads for ease in interpreting location, size and type of problems.

All maps and drawings should show constructed facilities "as built." If there was any change whatsoever from the construction plans, the maps and plans used by the utility should show this change. Whenever modifications are made, plans should be changed to show the details of the modification, the date of the modification, and who made the modification on the plans. The modified drawings are called "as-builts."

Plan and profile maps are engineering drawings which show the depth of pipe, pipe location both vertically and horizontally, and the correct distance from a reference starting point. Operators occasionally need to use this type of map. Water gradient contour maps are prepared by taking pressure readings during peak use periods over the system, calculating hydraulic gradients, placing these gradients on the comprehensive map and drawing in gradient contour lines. They can be used to indicate problem areas with insufficient or excessive pressures.

5.92 Types of Records

Written records should be kept on all facilities in the distribution system. These records should describe the facility, its construction, date installed, repair and maintenance work done, manufacturer, and condition during latest inspection. As new facilities are installed, they should be included in the existing record system. Records should also note those facilities retired from service. Other types of records to be kept include:



1. Results of water quality monitoring,
2. Cross-connection control,
3. Main flushing,
4. Main cleaning,
5. Consumer complaints,
6. Disinfection,
7. Pressure surveys,
8. Leaks,
9. Engineering reports,
10. Any operations done in compliance with the request of the Health Department, and
11. A daily log kept on any and all unusual events occurring, such as equipment malfunction, unusual weather conditions, and natural or man-made disasters.

Each public water system is required by the Primary Drinking Water Regulations to maintain records of water quality analyses, written reports, variances or exemptions and actions taken to correct violations of the regulations. The lengths of time these records must be kept are summarized in Table 5.7

TABLE 5.7 MINIMUM TIME PERIODS FOR RETAINING RECORDS

Record	Minimum Years of Retention
Bacteriological analyses	5
Chemical analyses	10
Written reports such as sanitary surveys, Engineering reports	10[a]
Variances or exemptions	5[b]
Action taken to correct violation	3[c]

[a] Following completion of surveys and reports.
[b] Following expiration of variance or exemption.
[c] After last action with respect to violation.

Important distribution system operational records include technical and maintenance information on pumps, meters, valves and other equipment. Information on design, capacities, and required maintenance should be kept with each major piece of equipment. Each piece of equipment should have its own file containing manufacturer's instructions, repairs made, and the schedule to be followed for routine maintenance. Each valve and hydrant should have a permanent file card such as that shown in Figure 5.52 and an inspection report form such as that shown in Figure 5.53.

Every utility should have a work order system which provides that all additions or changes to, or removal of, any of the system facilities be accomplished using approved work orders. Examples of some work order forms used are shown in Figure 5.54 and 5.55. The work order system should be devised to account properly for all of the physical plant facilities. The work order sketch (Figure 5.55), when completed, is used to revise the distribution maps to record additions, changes or removals.

QUESTIONS

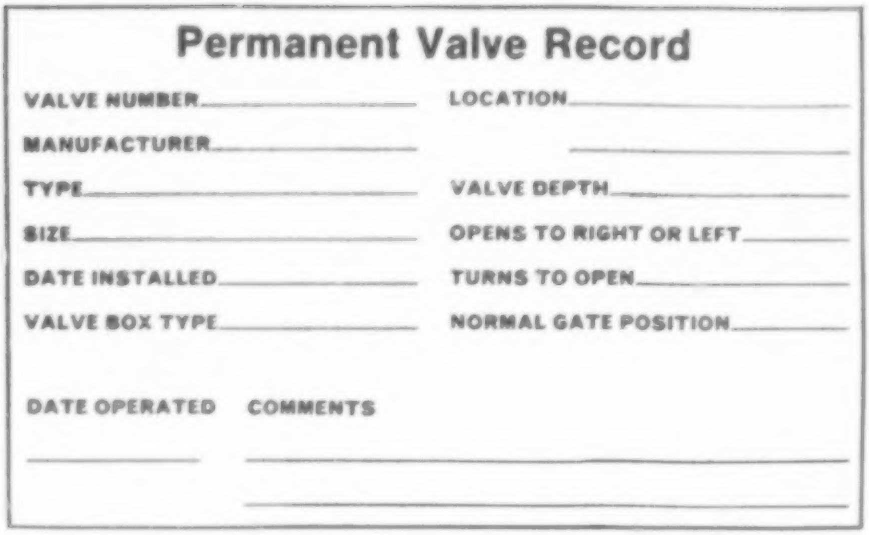
Write your answers in a notebook and then compare your answers with those on page 278.

5.9A What problems can develop if good records are not kept?

5.9B What is the purpose of a comprehensive map?

5.9C What information should be recorded on the "as built" plans whenever a change or modification is made to the system?

5.9D What information is shown on valve and hydrant maps?



Permanent Valve Record

VALVE NUMBER________ LOCATION________

MANUFACTURER________ ________

TYPE________ VALVE DEPTH________

SIZE________ OPENS TO RIGHT OR LEFT________

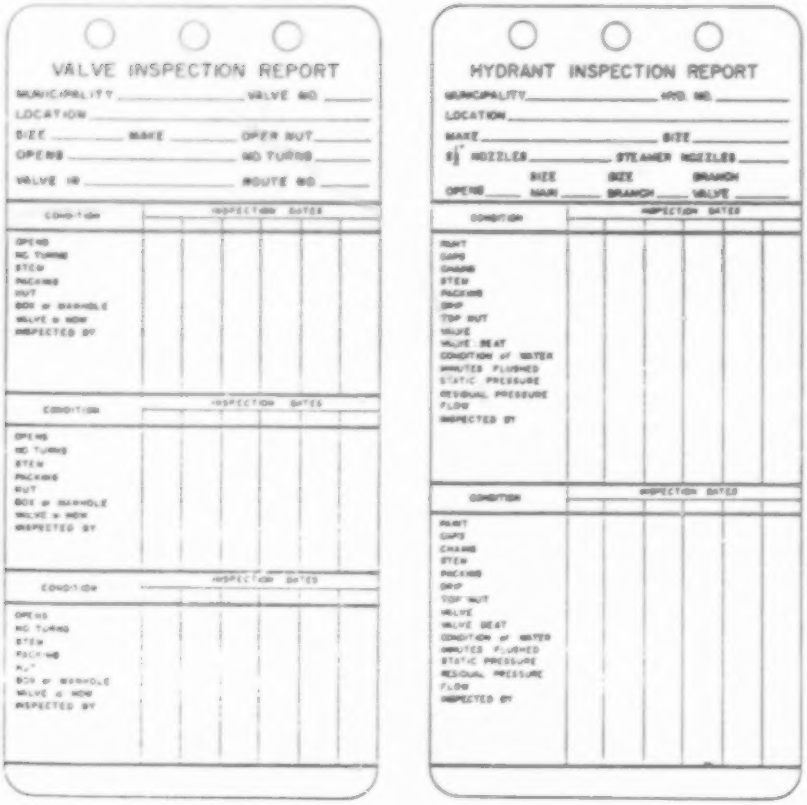
DATE INSTALLED________ TURNS TO OPEN________

VALVE BOX TYPE________ NORMAL GATE POSITION________

DATE OPERATED	COMMENTS

Fig. 5.52 Typical valve record form

(Reprinted from *OPFLOW*, January 1979, by permission. Copyright 1979, the American Water Works Association)



VALVE INSPECTION REPORT

MUNICIPALITY________ VALVE NO.________

LOCATION________

SIZE________ MAKE________ OPER NUT________

OPENS________ NO. TURNS________

VALVE IN________ ROUTE NO.________

CONDITION	INSPECTION DATES					
OPENS NO. TURNS STEM PACKING NUT BOX or MANHOLE VALVE in ROW INSPECTED BY						

CONDITION	INSPECTION DATES					
OPENS NO. TURNS STEM PACKING NUT BOX or MANHOLE VALVE in ROW INSPECTED BY						

CONDITION	INSPECTION DATES					
OPENS NO. TURNS STEM PACKING NUT BOX or MANHOLE VALVE in ROW INSPECTED BY						

HYDRANT INSPECTION REPORT

MUNICIPALITY________ HYD. NO.________

LOCATION________

MAKE________ SIZE________

2½" NOZZLES________ STEAMER NOZZLES________

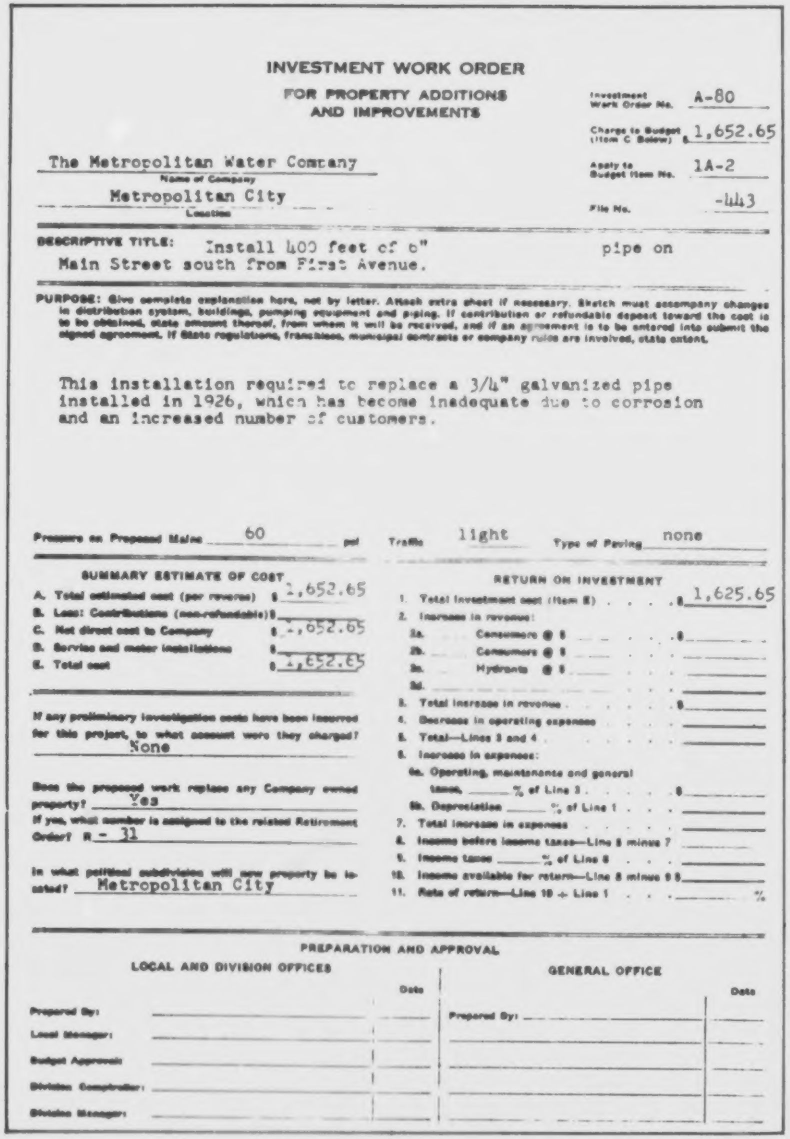
OPENS____ SIZE MAIN____ SIZE BRANCH____ BRANCH VALVE____

CONDITION	INSPECTION DATES					
PAINT CAPS CHAINS STEM PACKING DRIP TOP NUT VALVE VALVE SEAT CONDITION of WATER MINUTES FLUSHED STATIC PRESSURE RESIDUAL PRESSURE FLOW INSPECTED BY						

CONDITION	INSPECTION DATES					
PAINT CAPS CHAINS STEM PACKING DRIP TOP NUT VALVE VALVE SEAT CONDITION of WATER MINUTES FLUSHED STATIC PRESSURE RESIDUAL PRESSURE FLOW INSPECTED BY						

Fig. 5.53 Valve and hydrant inspection report forms

(Reprinted from *WATER DISTRIBUTION TRAINING COURSE*, by permission. Copyright 1962, the American Water Works Association)



INVESTMENT WORK ORDER

FOR PROPERTY ADDITIONS AND IMPROVEMENTS

Investment Work Order No. A-80

Charge to Budget (Item C Below) $ 1,652.65

Apply to Budget Item No. 1A-2

File No. -443

The Metropolitan Water Company
Name of Company

Metropolitan City
Location

DESCRIPTIVE TITLE: Install 400 feet of 6" pipe on Main Street south from First Avenue.

PURPOSE: Give complete explanation here, not by letter. Attach extra sheet if necessary. Sketch must accompany changes in distribution system, buildings, pumping equipment and piping. If contribution or refundable deposit toward the cost is to be obtained, state amount thereof, from whom it will be received, and if an agreement is to be entered into submit the signed agreement. If State regulations, franchises, municipal contracts or company rules are involved, state extent.

This installation required to replace a 3/4" galvanized pipe installed in 1926, which has become inadequate due to corrosion and an increased number of customers.

Pressure on Proposed Mains 60 psi Traffic light Type of Paving none

SUMMARY ESTIMATE OF COST

A. Total estimated cost (per reverse) $ 1,652.65
B. Less: Contributions (non-refundable) $
C. Net direct cost to Company $ 1,652.65
D. Service and meter installations $
E. Total cost $ 1,652.65

If any preliminary investigation costs have been incurred for this project, to what account were they charged? None

Does the proposed work replace any Company owned property? Yes

If yes, what number is assigned to the related Retirement Order? R - 31

In what political subdivision will new property be located? Metropolitan City

RETURN ON INVESTMENT

1. Total investment cost (Item E) . . . . $ 1,625.65
2. Increase in revenue:
2a. Consumers @ $ . . . . $
2b. Consumers @ $ . . . .
2c. Hydrants @ $ . . . .
2d. . . . .
3. Total increase in revenue . . . . $
4. Decrease in operating expenses . . . .
5. Total—Lines 3 and 4 . . . .
6. Increase in expenses:
6a. Operating, maintenance and general taxes, ____ % of Line 3 . . . . $
6b. Depreciation ____ % of Line 1 . . . .
7. Total increase in expenses . . . .
8. Income before income taxes—Line 5 minus 7
9. Income taxes ____ % of Line 8 . . .
10. Income available for return—Line 8 minus 9 $
11. Rate of return—Line 10 ÷ Line 1 . . . . %

PREPARATION AND APPROVAL

LOCAL AND DIVISION OFFICES

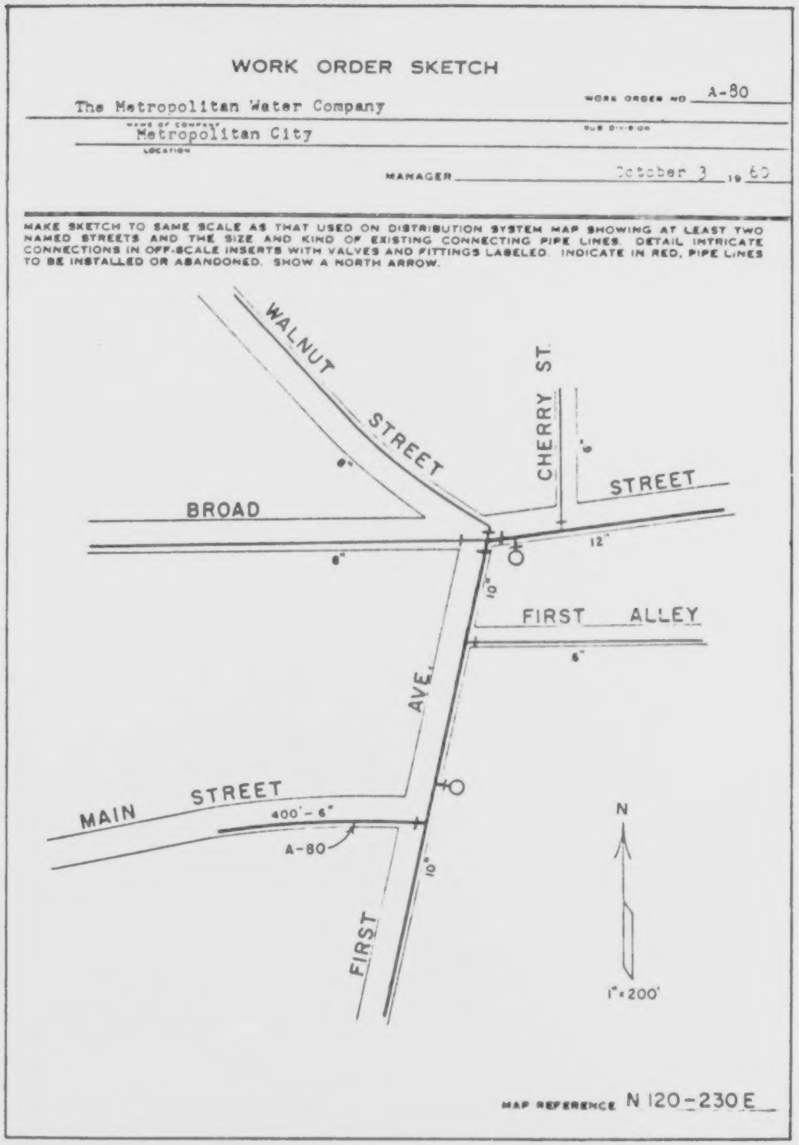
Prepared By: ____ Date ____
Local Manager: ____ Date ____
Budget Approval: ____ Date ____
Division Comptroller: ____ Date ____
Division Manager: ____ Date ____

GENERAL OFFICE

Prepared By: ____ Date ____

Fig. 5.54 Typical investment work order form

(Reprinted from WATER DISTRIBUTION TRAINING COURSE, by permission. Copyright 1962, the American Water Works Association)



WORK ORDER SKETCH

The Metropolitan Water Company
NAME OF COMPANY

WORK ORDER NO. A-80

SUB DIVISION

Metropolitan City
LOCATION

MANAGER ____ October 3, 19 60

MAKE SKETCH TO SAME SCALE AS THAT USED ON DISTRIBUTION SYSTEM MAP SHOWING AT LEAST TWO NAMED STREETS AND THE SIZE AND KIND OF EXISTING CONNECTING PIPE LINES. DETAIL INTRICATE CONNECTIONS IN OFF-SCALE INSERTS WITH VALVES AND FITTINGS LABELED. INDICATE IN RED, PIPE LINES TO BE INSTALLED OR ABANDONED. SHOW A NORTH ARROW.

MAP REFERENCE N 120-230 E

Fig. 5.55 Typical work order sketch

(Reprinted from WATER DISTRIBUTION TRAINING COURSE, by permission. Copyright 1962, the American Water Works Association)

5.10 EQUIPMENT AND STORES

Tools and equipment for distribution system operation and maintenance must be carefully selected according to the needs of the utility. The following points should be considered:

1. Cost and efficiency (including any resulting reduction in labor costs),
2. Shorter service interruptions,
3. Ability to make the job easier for the operators (a morale factor), and
4. Versatility of tools or equipment for use in different types of operation and maintenance tasks.

System requirements should be carefully analyzed to determine what is needed and how much should usually be kept on hand. A continuing stock inventory should be kept with the stock properly classified, described, and stored where it is easily located. Physical inventories (counts) should be periodically made, once or twice each year. An efficient record system is needed to provide for advance ordering of depleted items. The required items must be available on demand. Arrangements have to be made for proper handling and storing of supplies, equipment, parts, and other needed items.

The general types of equipment used include various hand tools such as picks, shovels, sledges, caulking tools, valve and hydrant wrenches. Also used are trench pumps, lighting equipment for night work, rubber boots, rain gear, mobile air compressors, power valve operators, excavators, pipe and leak locators, electric generators, ladders, rope, jacks, tamping and valve inserting tools, pipe pushers (Figure 5.56), mechanical joints, couplings, safety and first-aid equipment, signs, barricades, warning signals, and traffic cones. An emergency truck containing all of this needed equipment, ready to be sent out at a moment's notice, should be available. This properly staffed emergency vehicle should be able to handle a variety of system repairs and operation.

These and other supplies, equipment, materials and parts represent an appreciable part of the assets of a utility. Every water utility should also keep a basic stock of pipe and repair parts available for immediate use.

Motorized equipment is often categorized as (1) general purpose service trucks, (2) excavators (back hoes), (3) cranes of all types, (4) miscellaneous work equipment, and (5) specialized vehicles. Specialized vehicles include trucks used for meter maintenance, fire hydrant and valve maintenance, and emergency vehicles. Tractor backhoes have become the standard in most trenching operations. Pipe laying operations can proceed with the use of a motorized crane without interrupting excavation operations. Tractors equipped with front loader attachments can efficiently backfill excavations after pipe laying has been completed. Mechanical earth compactors or vibrating attachments for hydraulic tractors along with jetting will insure a compact trench backfill.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.10A What factors should be considered when selecting tools and equipment for distribution system operation and maintenance?

5.10B How frequently should physical inventories be made?

5.11 EMERGENCY PLANNING

Every water utility should have an emergency operations plan relating to disasters such as earthquakes, floods, hurricanes, tornadoes, and even war. Normally, this type of plan does not include "everyday" routine disruptions of service. The utility should have a separate plan that outlines what must be done when significant "routine" problems such as the following occur:

1. A key water main breaks,
2. An extended electrical power interruption occurs,
3. A vitally needed well pump motor or bearing "burns out,"
4. A key chlorinator or treatment unit fails, and
5. Test results or direct observations indicate the water supply has become contaminated.

Operators must recognize that these types of problems can also result from a disaster so some of the discussions in this section will apply to such "routine" problems. During a disaster, all of the above problems and more could take place at once with the entire system affected.

WHO?
WHAT?
WHEN?
YOU!
FIX!
NOW!

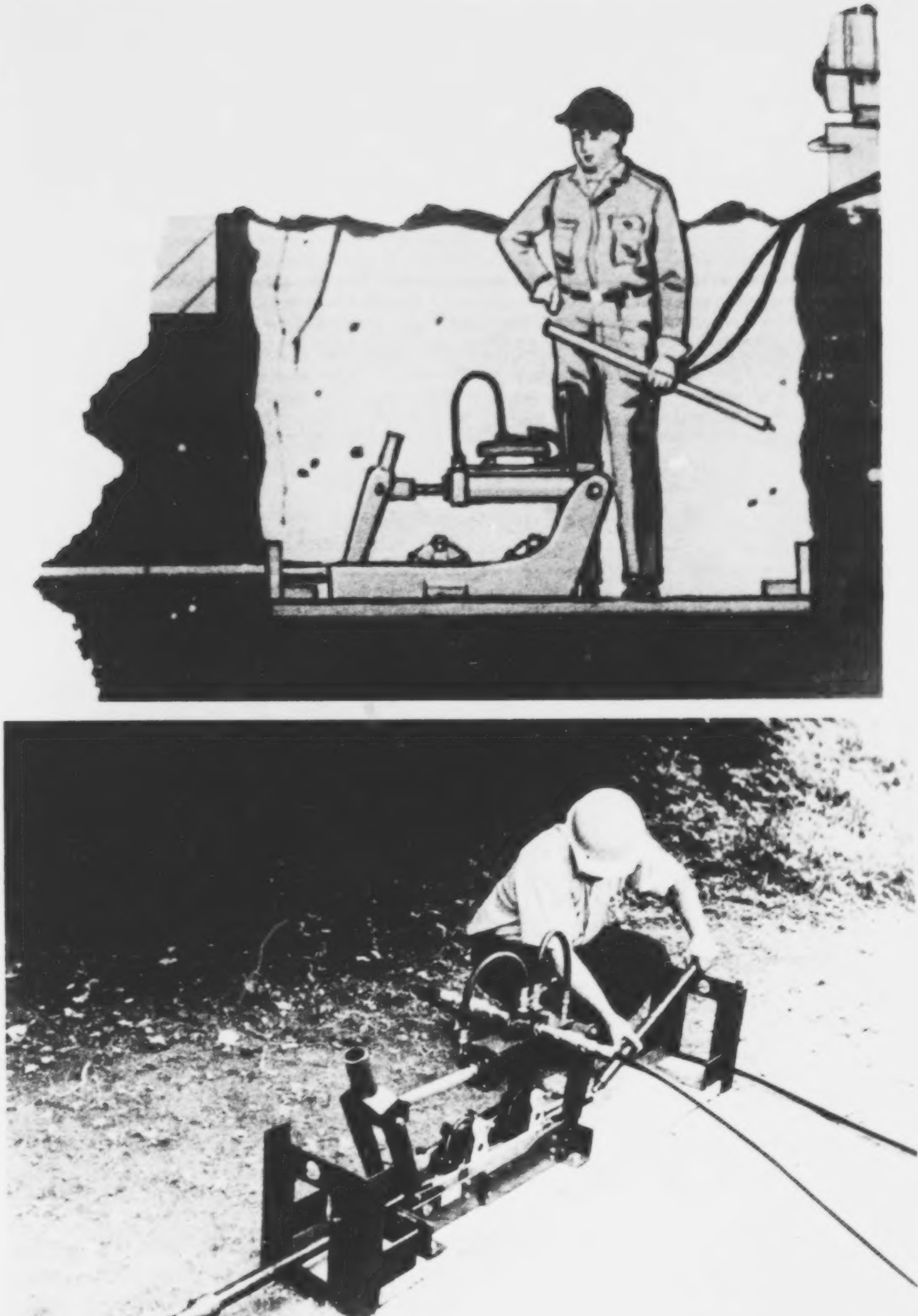


Fig. 5.56 Pipe pusher

(Permission of Trojan Manufacturing Company, Inc.)

An emergency operations plan has been defined simply as: "Under disaster conditions, *WHO* does *WHAT* and *WHEN* with the existing resources." The operations plan should be concise, giving guidance quickly at the time of need. If there is too much detail, the whole operation can get bogged down. The best plan is only a guide to action, but may be specific in some critical details. The plan must recognize that under emergency conditions, trained operators must react quickly and make on-the-spot decisions which must be appropriate to each level of responsibility. The emergency plan must be widely distributed, but also updated as needed as changes take place in staffing, equipment and facilities. All water utility operators must be familiar with the written plan and its location. If the plan is to be workable, effective training of personnel on a periodic basis (once a year) is required.

During a disaster, the water utility has the following prime responsibilities:

1. Provide water for fire fighting, drinking and sanitation,
2. Prevent unnecessary loss of stored water, and
3. Restore the integrity of the entire water system as soon as possible.

The first step in preparing for a disaster is to form a disaster organization. The disaster organization's staff and teams within the utility should be designated with alternates specified. An alerting list is needed with telephone numbers. The responsibilities of each individual with channels of command should be clearly defined. Related nearby utilities and local civil defense and military authorities should be contacted to establish liaison channels, to determine their own plans and what support is available from them, and obtain possible help in the utility's planning. "Mutual aid agreements" should be made where appropriate providing for exchange or assignment of personnel, equipment, and materials. The plan should contain work and home telephone numbers for all personnel of the disaster and mutual aid organizations, civil defense, police and fire departments, and state and local health departments.

An Emergency Operations Plan is developed by the disaster organization by first assuming a certain type of emergency and the resulting effects. The type of natural disaster a water utility might encounter depends on where it is located. Utilities on the West Coast can anticipate earthquakes or floods, on the East Coast hurricanes are not uncommon, while the Central United States is threatened by tornadoes. An estimate is made of the facilities, personnel and equipment capabilities remaining after the disaster and the requirements of the community. The capabilities are then matched to the requirements. The next three steps become the operations plan. First, priorities by which the requirements can be met are specified. Next, the best ways of using the available resources are designated. Finally, specific tasks are determined and are assigned to the assumed surviving or available personnel.

A vulnerability assessment should be made of the entire system to determine where the weaknesses are if the disaster being considered took place and what kind of improvements are feasible to reduce the weaknesses found. To do this, the separate components of the system are identified and described, including sources, collection works, transmission system, treatment facilities, distribution system, personnel, power supply, materials and supplies, and communications. The existing emergency plans and mutual-aid agreements are included in the assessment. Then, the effects of the assumed disaster on each component are estimated. Under the assumed conditions, water is allocated for fire fighting, potable, sanitary, decontamination, industrial, and livestock uses. The capability of the system to meet these requirements is then estimated and critical, suspect components identified.

Using the above information, the actual plan of operation during the emergency can be developed. Priorities are specified and the best apparent way of using the available resources outlined. A determination is made on how to allocate water under the assumed conditions for the uses specified above. Guidelines are prepared for water allowances, priorities, rationing (if appropriate), and time-phasing of estimated water requirements. Next, procedures are established for emergency treatment, pumping and distribution of water and for stations for service of emergency water. Restoring a system after a disaster may take weeks or longer and so it may be necessary to bring in hauled potable water and put it into intact facilities, or deliver it from tank trucks or other means directly to consumers. The public must be kept informed of the availability of potable water.

PURE
WATER
HERE

The vulnerable parts of the system, personnel, or equipment that were found from the vulnerability assessment can be reduced by a number of means. Facilities can be strengthened and, where appropriate, duplicated; alternative operation procedures can be made available; auxiliary booster, power and disinfection facilities can be obtained; stockpiles of materials and supplies can be increased; additional repair equipment can be obtained; and emergency procedures, communications and training given to disaster organization personnel can be improved.

Those operators who would like to have further information on this subject are referred to AWWA Manual M19, *EMERGENCY PLANNING FOR UTILITY MANAGEMENT*.[20]

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.11A Utilities should develop plans for responding to what types of routine disruptions which are normally not considered when developing disaster plans?

5.11B Define an Emergency Operations Plan.

5.11C List the three basic steps of an Emergency Operations Plan.

---

[20] *Obtain from Computer Services, AWWA, 666 W. Quincy Avenue, Denver, Colorado 80235. Order No. 30019. Price to members $13.00; nonmembers $16.00*

5.12 PUBLIC RELATIONS

Every employee of a utility is responsible for customer relations and for positive customer communication. Everything an employee does from meter reading, installing pipelines, repairing lines, flushing or answering consumer complaints has an effect on the public's image of the utility. System operators are often the most visible of the system's employees and at such times they can be considered as being in the front line of public relations. Some operators come into contact with the public incidentally, while others have direct intentional contact such as when dealing with consumer complaints. The system operator, therefore, must be aware of and take into account the responsibilities of public relations. Some water suppliers have recognized this fact and now call their meter readers water service representatives.

All employees communicate with the utility's customers in one way or another even if they do not realize it. If an employee operates an official vehicle in a reckless manner, appears to be idle while others are busy, does not know the answer to a question when asked, or is surly or uncooperative, the utility has communicated with its customers, but certainly not in the way it should have.

This added responsibility of representing the water supplier to the public means the operator must be careful to present a neat, efficient, knowledgeable, and cooperative image. Work habits should not encourage public criticism. Any encounter with the public, regulatory agencies or municipal officials should be viewed as an opportunity to provide valid information and to correct misunderstandings. All operators working for a water agency should have a basic knowledge of the system facilities and the system's operation. The public normally expects operators to have this knowledge and an operator appears to be uninformed and disinterested if simple questions about the agency cannot be answered.

All complaints should be treated as legitimate and investigated as soon as possible. If the person with the complaint is loud and abusive, the operator should not retaliate in kind. Instead, the operator should show concern, listen carefully and calmly, offer to look into the complaint and help correct any problems found. Questions should be asked as necessary to make certain the problem is understood. Every effort should be made to give the customer an immediate, clear and accurate answer to the problem in non-technical language. If the answer is not known, it should be referred to the proper person in the organization. Always inform the person with a problem what will be done to correct the situation or indicate when someone will call back with additional information. After the problem is corrected, a follow-up phone call or postcard to be sure everything is satisfactory is appropriate.

Sometimes it's only through complaints from its consumers that the water utility learns the service being given is not satisfactory. Complaint records should be reviewed periodically by responsible operators and they need to be especially looked at when numerous complaints start coming in. As previously mentioned in this chapter, if complaints are displayed on a map with the use of colored pins, a pattern might be detected which could indicate the area affected and where the investigation should center. By doing this routinely, the utility might be able to catch a problem at an early stage.

A customer's complaint may at times result from a problem that is originating on the customer's own premises. For example, a customer may complain about lack of water pressure such as often results from deficiencies in the customer's own plumbing. Pressure readings should be taken in the house, first without any flow so as to obtain a reading which should be close to the pressure in the system main. Then a pressure test is made with other taps in the house flowing to show the pressure drop was due to some obstruction or inadequate plumbing. Often, this may be due to the shut-off valve on the house water line being turned off or partially off. If this is not the cause of failure, the owner must usually make corrections to the plumbing. Replacing the service line from the meter to the house is often sufficient; however, occasionally repairs to the plumbing in the house may also be necessary.

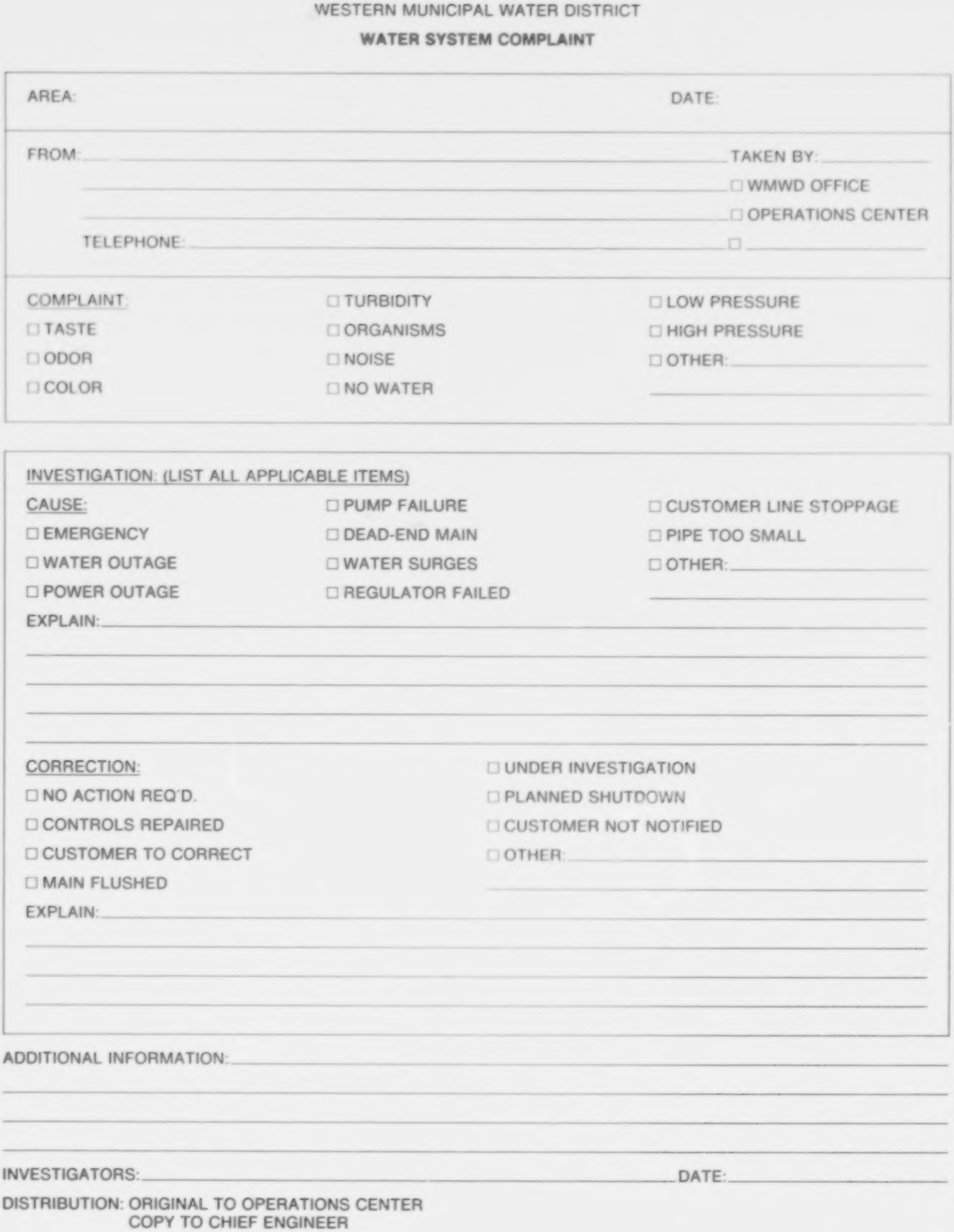
Another problem that is not uncommon is red or dirty water which could also be due to deficiencies in the consumer's own lines. The cause of the problem can be demonstrated by taking samples from the customer's tap and comparing them with samples of water collected from the utility's service line just upstream of the consumer's system. Another indication of the source is that if no other home in the area has, or has recently had, this problem, it almost certainly is coming from the consumer's plumbing.

The operator may also receive complaints that some persons in a home are becoming ill, with this emphatically attributed to the water they are drinking. These complaints should be thoroughly investigated by the utility agency and also referred to the health department. Sometimes the consumer's doctor says that the water supply is at fault (or so the consumer claims). If this takes place, the doctor should be referred to the health officer. Often, a bacteriological sample is collected directly from the consumer's home. If water quality test results are negative and the customer's neighbors and the rest of the community have no problems, it is very doubtful that the utility's supply is the culprit.

To record all the necessary information, many agencies use a complaint form such as that shown in Figure 5.57.

Some utilities go directly to their customers to find out how the customers feel about the system and its operation. Figure 5.58 was prepared as part of an over-all plan of utility self-evaluation, consumer opinion, follow-up with consumer, and development of a capital-construction improvement program. The questionnaire was designed to ask questions a lay person could understand and was successfully field tested in two water utilities. From the responses received, problems can be identified and priorities can be designated as to which problems can be solved soon and which must await solution at some later date.

For an excellent discussion on how to solve problems causing complaints, see Section 10.111, "Investigating Com-



WESTERN MUNICIPAL WATER DISTRICT

WATER SYSTEM COMPLAINT

AREA: DATE:

FROM: ______ TAKEN BY: ______

☐ WMWD OFFICE

☐ OPERATIONS CENTER

☐ ______

TELEPHONE: ______

COMPLAINT:

☐ TASTE
☐ ODOR
☐ COLOR

☐ TURBIDITY
☐ ORGANISMS
☐ NOISE
☐ NO WATER

☐ LOW PRESSURE
☐ HIGH PRESSURE
☐ OTHER: ______

INVESTIGATION: (LIST ALL APPLICABLE ITEMS)

CAUSE:

☐ EMERGENCY
☐ WATER OUTAGE
☐ POWER OUTAGE

☐ PUMP FAILURE
☐ DEAD-END MAIN
☐ WATER SURGES
☐ REGULATOR FAILED

☐ CUSTOMER LINE STOPPAGE
☐ PIPE TOO SMALL
☐ OTHER: ______

EXPLAIN: ______

CORRECTION:

☐ NO ACTION REQ'D.
☐ CONTROLS REPAIRED
☐ CUSTOMER TO CORRECT
☐ MAIN FLUSHED

☐ UNDER INVESTIGATION
☐ PLANNED SHUTDOWN
☐ CUSTOMER NOT NOTIFIED
☐ OTHER: ______

EXPLAIN: ______

ADDITIONAL INFORMATION: ______

INVESTIGATORS: ______ DATE: ______

DISTRIBUTION: ORIGINAL TO OPERATIONS CENTER
COPY TO CHIEF ENGINEER

Fig. 5.57 Sample water system complaint and investigation form

SAMPLE QUESTIONNAIRE

(A low-cost format for general use by systems of all sizes)

Please rate us. Where you rate us low we'll try to improve. Or explain why we don't think we can. Please return this rating form when you pay your bill.

1. Do you think you have good water service generally? (circle one)
   Always Usually Half the time Occasionally Never

2. Is your water pressure too high?
   Always Usually Half the time Occasionally Never

3. Is your water pressure too low?
   Always Usually Half the time Occasionally Never

4. Is your water dirty or off-color?
   Always Usually Half the time Occasionally Never

5. Do you avoid sprinkling in summer because water costs so much?
   Always Usually Half the time Occasionally Never

6. Have you had to complain about your service in the last two years?
   Yes Can't Recall No

7. Do you know who to call if you have a complaint? Yes No

8. Are you treated courteously when you talk to water utility people?
   Always Usually Half the time Occasionally Never

9. Do you get prompt action when you ask them for something?
   Always Usually Half the time Occasionally Never

10. Is your water bill too high for the service you get?
    Always Usually Half the time Occasionally Never

11. Please tell us on the back of this sheet if you have a specific complaint or comment.

Thanks for your help. Do NOT sign your name unless you have a complaint and want someone to call you. We'll let you know the outcome of this survey.

Fig. 5.58 Water utility evaluation form

(Source: *THE SAFE DRINKING WATER HANDBOOK FOR WATER SYSTEM OPERATORS*, prepared by the American Water Works Association) plaints," page 444, in *WATER TREATMENT PLANT OPERATION*, Volume I, of this series of manuals. The section describes the more common types of consumer complaints, investigation procedures, and the possible causes for complaints.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.12A What kind of an image should an operator present to the public?

5.12B How would you attempt to determine the cause of a customer's complaint regarding low water pressure?

5.13 LANDSCAPING

5.130 Purpose of Landscaping

Landscaping enhances the appearance of water supply and treatment facility sites. When people drive by well pumping sites, water storage facilities, and booster pumping stations, many may have preconceived thoughts. A well manicured lawn, trimmed shrubs, along with a variety of ground cover will provide a positive "first impression." Take pride in your facilities and it will be apparent to all who drive by or visit your facilities.

When facilities are designed and built, landscaping is a very important part of the construction. Usually landscaping is well done by professionals. Our responsibility is to maintain that investment and appearance.

The following paragraphs will shed light on how to best achieve adequate landscape appearance and yard maintenance.

5.131 Irrigating

If your facility is one of many that enjoy a beautiful green lawn, you know the importance of proper watering and water coverage. If your sprinkler system was installed by a competent private contractor, chances are it was engineered to provide adequate lawn coverage. A good indication that coverage is inadequate is a non-uniform appearance of the lawn. The sprinkler drops the greatest amount of water near the head and very little at its outer limits. The small amount of water doesn't penetrate very deep and the grass roots are very shallow. The weak grass allows for weeds such as dandelion, sorrel, and plantain, that can take less water than typical lawn grasses. On the other hand, spots that are subject to too much water invite sedge, crabgrass, chickweed, and annual blue grass. The best answer to unequal water distribution is to alternate the sprinklers and wetting pattern.

When and how often do you water? Grass shows its need for water first by loss of resilience. When you walk on grass needing water, there is no spring back. Next, the color changes from a fresh green to a dull gray-green. The grass tops turn brown and die in the next stage. Ideally you should water before the no-spring back sign begins. After living with a lawn for a while you can sense that timing. Deep watering once a week is recommended. This causes plants to root deeper. As water is drawn from the soil by the grass roots, more air enters the ground and a better growth environment is created. Long slow watering will allow for good penetration. A three-hour application is quite common. Depending upon the type of soil you have, water penetration will be approximately one inch during the proper watering period.

Some of the reasons for not using light, frequent waterings are:

1. Greater water use,
2. Shallow rooting of grass,
3. Encouragement of shallow-rooted weeds,
4. Greater soil compaction, and
5. Rapid buildup of salinity due to lack of leaching.

5.132 Controlling Weeds

If we always grew only what we sowed originally in a lawn, the task of keeping a lawn would be easier. The trouble is that soils are generally full of dormant weed seeds waiting for the right conditions to germinate. Weed seed is also present in lawn seed mixtures to a small degree. Wind and birds help bring in new seeds. We will always have weeds. The question is how to get rid of them. There is a wide variety of chemical weed killers (herbicides) available. Most herbicides are selective and control a specific type of weed. They fall into two classes, broadleaf and grassy.

The term "broadleaf" is used to describe non-grassy weeds. A few of the familiar ones are: dandelion, curly dock, chickweed, bur clover, oxalis, knotweed, and English daisy. The hormone-type weed killers such as 2,4D and 2,4,5-TP are the best known of the herbicides. They kill broadleaf plants by speeding growth so the plants literally grow themselves to death. Depending on the species, weeds may require one to four treatments to obtain a good kill. This type of chemical is absorbed by the leaves and carried through the system to the roots. Both tops and roots are killed. Weeds treated with chemicals show curled and twisted stems in the first stage. Finally, the roots are expanded and ruptured and the entire plant dies. Select a weed killer that kills the entire plant. Burning the leaf may indicate a kill, but a vigorous root system could survive and cause regrowth.

The grassy weeds are also all too familiar: Burmuda grass, quackgrass, nutgrass, velvet grass, and orchard grass. One thing to remember if you are applying a chemical to control grassy weeds: it can also kill the lawn grasses. Therefore, it is best to do controlled spot killing in the affected areas. Spot application of dalapon or amitrol will generally take care of local grasses. Be sure to follow label directions closely. If your lawn is overcome by grassy weeds, it may be necessary to use a soil fumigant. The fumigant chemically kills almost everything in the soil and leaves it sterile. Three commonly used fumigants are Vapam, Mylone, and calcium cyanamid. If applying the chemical yourself, follow directions closely.

If you are faced with a large weed-control problem, hire a professional. There are commercial companies who are knowledgeable and capable of handling your problem. When faced with weeds that grow along chain link fences or soil around buildings, a light application of diesel fuel will do the trick. All you need is a handheld pressure sprayer to insure adequate coverage. Do your spraying on calm days without wind. The objective is to kill only the selected weeds and grasses. When the wind kicks up, discontinue application until the wind dies down again.

5.133 Fertilizing

Grass has a continual need for nitrogen. Nature does a poor job of supplying that nutrient in quantities necessary to keep plants growing thick, green, and dense. If a lawn turns yellow or pale green or if grass becomes thin and weeds come in, it is probably an indication that nitrogen is needed. If you apply a fertilizer containing nitrogen and the lawn does not respond, then suspect other trouble such as disease, lack of air, or grubs and other larvae.

When you purchase a fertilizer, the three-number formula such as 6-4-2 indicates first the percentage of nitrogen, second the percentage of phosphorus, and third the percentage of potassium. Consider the phosphorus and potassium as a bonus to lawn feeding. The ever-important nitrogen comes in several forms. Some types are slow acting and may take a number of weeks or months for the nitrogen to be fully used by the lawn. Other forms are fast acting and immediate results can be seen in just a few days. When reading labels, remember not all organics are slow acting and not all inorganics are fast acting. The rate of availability grades down from immediate to gradual over a period of months.

Here are the meanings of the words on the fertilizer label that refer to nitrogen:

NITRATE. The form of nitrogen that is available to the plant as is, regardless of temperatures.

AMMONICAL OR AMMONIC. Available to plants when converted by bacteria to nitrate. Speed of conversion depends upon soil temperatures.

ORGANIC. Describes sludge, cottonseed meal, and any other materials that must first be broken down by bacteria.

UREA. A synthetic organic that water and the enzyme urease change immediately to inorganic ammonia. The ammonia is then converted to nitrate.

UREA FORM OF UREA FORMALDEHYDE. A nitrogen fertilizer that has been specially compounded for slow release.

How often do you feed a lawn? The color of the grass can show nitrogen need. An easy method used to determine need is the number of times per week or month that the lawn needs cutting. At the start, if cuttings were done every five to eight days and then extended to eight to fourteen days, more fertilizer is needed. Depending on the fertility of the lawn soil, grass will show a loss of color in four to eight weeks after fertilization. Thus, the feed-when-it-needs-it method could require fertilizer from three to twelve times a year. If fertilizing is a problem, then feed the lawn adequately in the spring and fall. This procedure may not be quite as effective as desirable, but the lawn should do quite well.

How much do I feed the lawn? A rule of thumb is one pound actual nitrogen for every 1,000 square feet of lawn per month (this applies only to the growing months). To figure actual nitrogen needs, take the percentage stated on the label times the weight of the fertilizer. For example a 20-pound bag (it could be liquid) containing 15 percent nitrogen will yield approximately 3 pounds of nitrogen or enough to feed 3,000 square feet for a month (20 pounds times 0.15 equals 3.0 pounds nitrogen).

Fertilizer should be distributed as evenly as possible. The most effective applicator is a hopper spreader. Four common mistakes when using the spreader are:

1. You cannot turn an open hopper inside a previous turn. The square corner will allow for excessive fertilizer application at that point.
2. You cannot stop and start with the hopper open. Walking at an unsteady pace will do the same thing.
3. Do not overlap with fertilizer.
4. Do not make 180-degree turns. Since one wheel is still driving the sifter, dispersal on the turn is very erratic.

After applying fertilizer, water the lawn heavily. Most fertilizers require a soaking to get the action started. This also prevents burning the grass blades.

5.134 Mowing and Pruning

Mowing and pruning are very important. Lawns must be mowed and edged at regular intervals to maintain their appearance. Trees and shrubs should be kept pruned so they won't interfere with the operation and maintenance of the plant, as well as to appear neat.

5.135 Surface Water Drainage

Depending on the location of your plant, drainage of storm water runoff and other surface water runoff can be very important. No one wants unwanted water running into buildings or flooding roadways and walkways. Provisions to handle this water should have been made when the plant was designed. Maintenance of these facilities requires keeping all curb drains and crop inlets free of leaves and other debris. Also, the storm drain lines must be clear and ready to handle any runoff. Sump pumps in the drainage system should be included in a regular preventive maintenance program, depending on the type, size, and frequency of use of the pumps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 278.

5.13A How do weed seeds get in a lawn?

5.13B How could you tell if a lawn needs nitrogen?

5.14 ARITHMETIC ASSIGNMENT

There are four additional types of distribution system problems that have not been covered in the previous material in this manual. These problems are encountered by operators in the operation and maintenance of distribution systems and you should know how to work them.

FORMULAS

1. Trench Excavation

When excavating a trench for a pipeline, you need to be able to calculate the volume of soil removed in cubic yards.

$$\text{Volume, cu ft} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})$$

and

$$\text{Volume, cu yd} = \frac{(\text{Volume, cu ft})}{27 \text{ cu ft/cu yd}}$$

2. Volume of Flow

If you are given a flow meter reading in gallons per minute (GPM), you can calculate the total flow volume if you know the length of time.

$$\text{Flow Volume, gal} = (\text{Flow Rate, gal/min})(\text{Time, min})$$

If you are given the volume of a tank and the flow rate in gallons per minute (GPM), you can calculate the time required to fill a tank.

$$\text{Time Required, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

3. Reservoir Storage

Earlier in this manual we calculated the volume of water in a tank or reservoir using the following formulas:

a. Rectangular

$$\text{Volume, cu ft} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})$$

b. Cylindrical

$$\text{Volume, cu ft} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})$$

To convert the volume from cubic feet to gallons, we multiplied by 7.48 gal/cu ft.

$$\text{Volume, gal} = (\text{Volume, cu ft})(7.48 \text{ gal/cu ft})$$

Many operators calculate the volume of water in gallons per each foot of water depth in their storage reservoirs. With this constant number, they measure the depth of water in feet and multiply this depth by the constant in gallons per foot to determine the volume in gallons.

For a cylindrical tank,

$$\text{Volume, gal} = (\text{Area, sq ft})(\text{Depth, ft})(7.48 \text{ gal/cu ft}).$$

The area times 7.48 gal/cu ft will give us a constant and then we multiply this constant times the depth to obtain the volume in gallons. With this constant we can also develop an elevation (depth) versus storage curve so that for any depth of water we obtain the storage or volume in gallons from the curve.

4. **Measurement of Flow from a Hydrant (Figure 5.59)**

When flushing water mains the flow can be estimated by measuring the pipe diameter (D) or diameter (D) of the water jet flowing out of the hydrant, the distance or height (H) the water drops down to the ground and the distance (L) the water shoots out from the hydrant before hitting the ground. All three of the values must be measured in inches.

$$\text{Flow, GPM} = \frac{2.83 (\text{Diameter, in})^2(\text{Length, in})}{\sqrt{\text{Height, in}}}$$

EXAMPLE 11

A trench three-feet wide, 1400-feet long and eight-feet deep is to be excavated for a water main. How many cubic feet and also cubic yards of soil have to be excavated for the water main?

Known	Unknown
Length, ft = 1400 ft	1. Volume Excavated, cu ft
Width, ft = 3 ft	2. Volume Excavated, cu yd
Depth, ft = 8 ft	

1. Calculate the volume excavated in cubic feet.

$$\begin{aligned}\text{Volume, cu ft} &= (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})\\ &= (1400 \text{ ft})(3 \text{ ft})(8 \text{ ft})\\ &= 33{,}600 \text{ cu ft}\end{aligned}$$

2. Calculate the volume excavated in cubic yards.

$$\begin{aligned}\text{Volume, cu yd} &= \frac{\text{Volume, cu ft}}{27 \text{ cu ft/cu yd}}\\ &= \frac{33{,}600 \text{ cu ft}}{27 \text{ cu ft/cu yd}}\\ &= 1244 \text{ cu yd}\end{aligned}$$

EXAMPLE 12

A flow meter indicates a flow rate of two gallons per minute. How many gallons of water will flow through the meter in two hours?

Known	Unknown
Flow Rate, GPM = 2 GPM	Flow Volume, gal
Time, hr = 2 hr	

Calculate the total volume of water in gallons.

$$\begin{aligned}\text{Flow Volume, gal} &= (\text{Flow Rate, gal/min})(\text{Time, hr})(60 \text{ min/hr})\\ &= (2 \text{ gal/min})(2 \text{ hr})(60 \text{ min/hr})\\ &= 240 \text{ gal}\end{aligned}$$

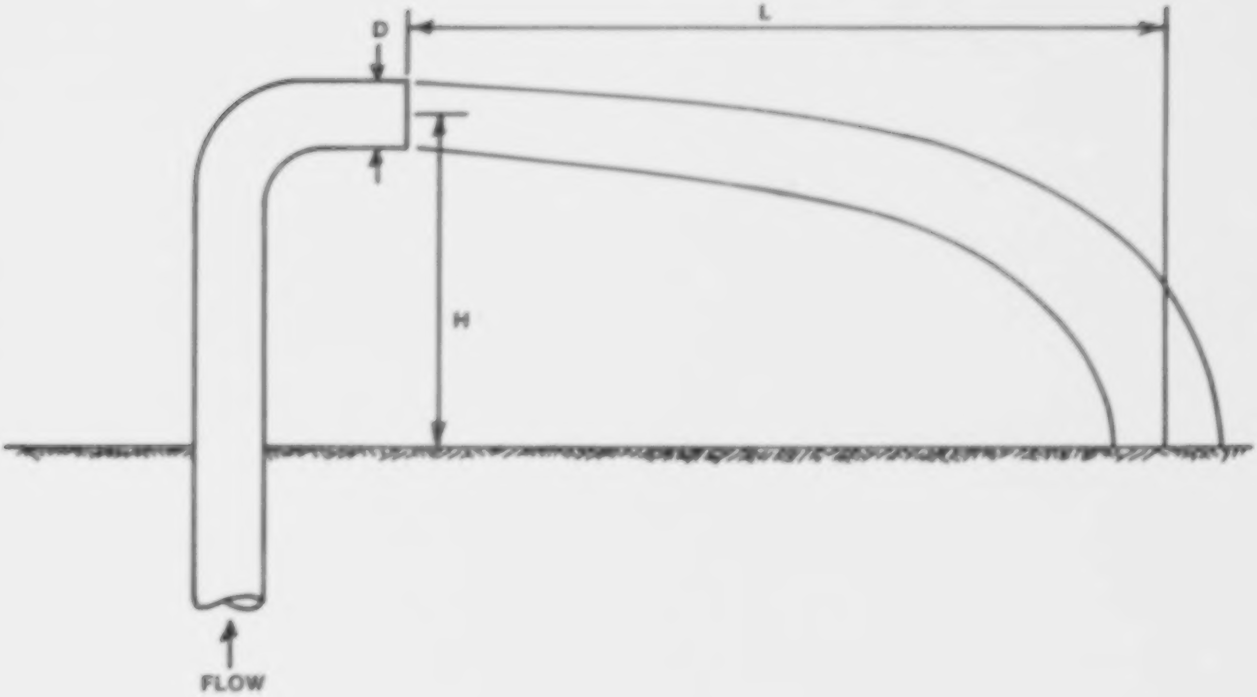
EXAMPLE 13

A chemical solution tank is four feet in diameter and five-feet deep. How long will it take to fill this tank when water flows in at a rate of two gallons per minute?

Known	Unknown
Diameter, ft = 4 ft	Time to Fill, min
Depth, ft = 5 ft	
Flow Rate, GPM = 2 GPM	

1. Calculate the tank volume in gallons.

$$\begin{aligned}\text{Tank Volume, gal} &= (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48 \text{ gal/cu ft})\\ &= (0.785)(4 \text{ ft})^2(5 \text{ ft})(7.48 \text{ gal/cu ft})\\ &= 470 \text{ gal}\end{aligned}$$



$$Q,\ GPM = \frac{2.83\ (DIAMETER,\ IN.)^2\ (LENGTH,\ IN.)}{\sqrt{HEIGHT,\ IN.}}$$

Fig. 5.59 Measurements for estimating flow

2. Calculate the time to fill the tank in minutes.

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

$$= \frac{470\ \text{gal}}{2\ \text{gal/min}}$$

$$= 235\ \text{min}$$

3. Convert 235 minutes to hours and minutes.

$$\text{Time to Fill} = \frac{235\ \text{min}}{60\ \text{min/hr}}$$

$$= 3.917\ \text{hr}$$

$$= 3\ \text{hr} + (0.917\ \text{hr})(60\ \text{min/hr})$$

$$= 3\ \text{hr} + 55\ \text{min}$$

EXAMPLE 14

A cylindrical water storage tank is 10 feet in diameter and 20 feet high. Calculate the gallons of water per foot of depth and then the total gallons when the water is five feet deep.

Known	Unknown
Diameter, ft = 10 ft	1. Volume, gal/ft
Height, ft = 20 ft	2. Volume, gal (for Depth = 5 ft)
Depth, ft = 5 ft	

1. Calculate the volume of water in the tank per foot of depth.

$$\text{Volume, gal} = (\text{Area, sq ft})(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$\text{Volume, gal/ft} = (0.785)(\text{Diameter, ft})^2(7.48\ \text{gal/cu ft})$$

$$= (0.785)(10\ \text{ft})^2(7.48\ \text{gal/cu ft})$$

$$= 587\ \text{gal/ft}$$

2. Calculate the volume of water in the tank in gallons when the water is five feet deep in the tank.

Volume, gal =(Volume, gal/ft)(Depth, ft)

= (587 gal/ft)(5 ft)

= 2935 gal

EXAMPLE 15

Using the 10-foot diameter tank that is 20 feet high from the previous example, and the constant, 587 gal/ft, prepare an elevation (depth) versus storage curve for the tank.

Known		**Unknown**
Diameter, ft	= 10 ft	Depth versus storage
Height, ft	= 20 ft	
Constant, gal/ft	= 587 gal/ft	

To prepare the depth versus storage curve, determine the storage in gallons for three or more water depths. In this example we will use depths of 5 ft, 10 ft, 15 ft and 20 ft.

Volume, gal = (Constant, gal/ft)(Depth, ft)

For 5 ft

Volume, gal = (587 gal/ft)(5 ft)

= 2935 gal

For 10 ft

Volume, gal = (587 gal/ft)(10 ft)

= 5870 gal

For 15 ft

Volume, gal = (587 gal/ft)(15 ft)

= 8805 gal

For 20 ft

Volume, gal = (587 gal/ft)(20 ft)

= 11,740 gal

SUMMARY OF RESULTS

Depth, ft	Storage, gal
5	2,935
10	5,870
15	8,805
20	11,740

To prepare depth versus storage curve, plot the summary of results as shown in Figure 5.60. Draw a line of best fit (a straight line in this case) through the plotted points. If we measure a depth of water of 12 feet, we could go to the curve and obtain a storage volume of 7050 gallons. The larger the curve, the more accurate the readings that can be obtained

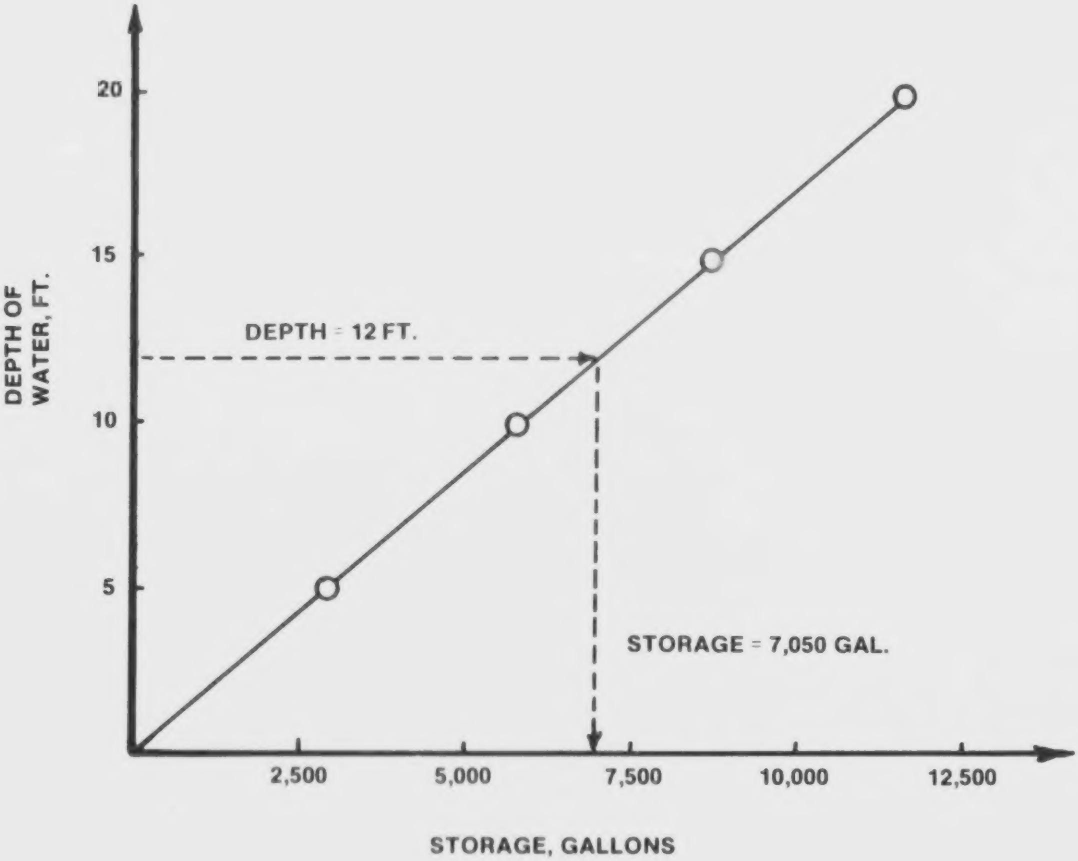


Fig. 5.60 Depth versus storage curve for example 15

EXAMPLE 16

Estimate the flow from a hydrant if the water is flowing out a pipe two inches in diameter. The water drops 36 inches before hitting the ground a distance of 60 inches away from the hydrant (see Figure 8.59).

Known	Unknown
Diameter, in = 2 in	Flow, GPM
Height, in = 36 ft	
Length, in = 60 in	

Estimate the flow from the hydrant in gallons per minute.

$$\text{Flow, GPM} = \frac{2.83\ (\text{Diameter, in})^2(\text{Length, in})}{\sqrt{\text{Height, in}}}$$

$$= \frac{(2.83)(2\text{ in})^2(60\text{ in})}{\sqrt{36\text{ in}}}$$

$$= \frac{(2.83)(4)(60)}{6}$$

$$= 113\text{ GPM}$$

Turn to the Appendix at the back of this manual and read all of Section A.8, "Pumps."

In Section A.13, "Typical Water Distribution System Problems," read and work the problems in Section A.133, "Distribution System Operation and Maintenance."

Check all of the arithmetic in these two sections on an electronic pocket calculator. You should be able to get the same answers.

5.15 ADDITIONAL READING

1. *NEW YORK MANUAL*, Chapter 3, "Hydraulics and Electricity," and Chapter 17, "Protection of Treated Water."
2. *TEXAS MANUAL*, Chapter 15, "The Distribution System," and Chapter 17, "Customer Meters."
3. *WATER DISTRIBUTION OPERATOR TRAINING HANDBOOK*. Available from Computer Services. AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 20103. Price to members, $13.00; nonmembers, $16.50.
4. A TRAINING COURSE IN WATER DISTRIBUTION (M8). Available from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 30008. Price to members, $10.50; nonmembers, $13.00.
5. *INTRODUCTION TO WATER DISTRIBUTION*. Available from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235, 1987. Order No. 1916. Price, $27.50.
6. *CROSS-CONNECTION CONTROL MANUAL* (EPA-430/973-002), available from ORD Publications, Center for Environmental Research Information, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268. Also available from Superintendent of Documents. U.S. Government Printing Office, Washington, D.C. 20402. Stock Number 055-001-00614-4. Price $2.50.
7. *THE WATER AUDIT AND LEAK DETECTION GUIDEBOOK*. Available free from Central Records, Room 338, California Department of Water Resources, PO Box 942836, Sacramento, CA 94236-0001.

5.16 ACKNOWLEDGMENTS

The authors of these three chapters on distribution systems wish to thank the American Water Works Association for graciously granting permission to reproduce material from the many excellent AWWA publications, including the operator publication *OPFLOW*. Also thanks are given to the many manufacturers who granted us permission to use their material.

End of Lesson 4 of 4 Lessons
on
DISTRIBUTION SYSTEM
OPERATION and MAINTENANCE

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

(Lesson 4 of 4 Lessons)

Write the answers to these questions in your notebook before continuing with the Objective Test on page 279. The question numbering continues from Lesson 3.

23. When should distribution system mains and reservoirs be disinfected?
24. Why is the slug method of chlorine disinfection advantageous for use with long, large diameter mains?
25. What factors would you consider when selecting a method for using chlorine to disinfect a storage facility?
26. Why should good records be prepared and kept?
27. Why should utilities have a work order system?
28. What are the prime responsibilities of a water utility during a disaster?
29. How should complaints be handled?
30. How would you respond to a customer's complaint that the water they are drinking is making them ill?

SUGGESTED ANSWERS

Chapter 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 186.

5.0A Water suppliers meet their *LEGAL* responsibility to deliver safe water to their customers through the conscientious operation and maintenance of the system facilities.

5.0B The objective of distribution system maintenance is the maximum continuous service of the equipment in the system at the lowest possible cost to the utility.

Answers to questions on page 187.

5.1A Water distribution system surveillance elements that should be considered include vandalism, storm damage, reservoirs, underground storage, pump stations and valves.

5.1B Critical parts of a distribution system should be patrolled on a routine basis to provide the utility with an early warning of any adverse conditions that might appear.

5.1C Daily surveillance of a reservoir should include a check to see if there has been any trespassing, vandalism, dumping of trash or swimming. Particular attention should be paid to fence and screen openings, roof damage, locks on reservoirs and to manholes or doors. Reservoir roofs should be water tight and vent screens should cover openings.

5.1D Weekly inspections of reservoirs should note any algae, slime and/or worm growths; floating or settled materials; or deterioration of roofing and wooden trusses.

Answers to questions on page 188.

5.1E Field crews should be on the lookout for any unauthorized construction activity or soil erosion near the utility's pipelines because these activities could damage the water distribution system, especially buried pipes.

5.1F Valves and valve boxes should be inspected annually.

5.1G Air-relief valves should be inspected after rains or floods to assure that they are not submerged in drainage water.

Answers to questions on page 189.

5.1H If vandalism or illegal entry is discovered, make a thorough investigation to determine what damage might have been done and whether there is any possibility of a threat to the quality of the water supply. Record the condition of all locks, any questionable conditions in the areas where unauthorized entry apparently took place, presence of hazardous material containers, missing items, and damaged equipment. Report your findings to the appropriate authorities (supervisor and police).

5.1I Water quality tests that can be quickly made are turbidity, chlorine residual, conductance, pH, and alkalinity. Tests should also be done for coliforms.

5.1J If an operator discovers a vandal in a water distribution system facility, the authorities (supervisor and police) should be immediately notified. The operator should not attempt to use force on a vandal because the operator could be injured.

5.1K Information that can be telemetered includes elevations in reservoirs or tanks, pump discharge rates, pressures in mains and rate of flow. Water quality data can include residual chlorine and turbidity. Telemetering can also be used to start and stop pumps and to open and close valves.

Answers to questions on page 191.

5.2A Requirements for total trihalomethanes apply to community water systems which chlorinate their water supplies and serve 10,000 or more people.

5.2B National Secondary Drinking Water Regulations apply to contaminants which may adversely affect the aesthetic quality of the drinking water and result in consumer rejection of the water provided.

5.2C More samples than the minimum required would be collected where sanitary hazards exist or when levels of contaminants approach or exceed maximum contaminant levels.

Answers to questions on page 192.

5.2D Samples are routinely collected from water distribution systems and tested for (1) coliform bacteria, (2) turbidity, (3) total trihalomethanes, (4) chlorine residuals and (5) physical quality (tastes and odors).

5.2E Utilities attempt to maintain chlorine residuals throughout the system to protect the public health, control coliform aftergrowths, and to serve as an indicator that the water is free from contamination.

5.2F The sudden absence of a chlorine residual in a water distribution system should alert the operator to the possibility that a problem has arisen which needs prompt investigation. Possible action includes retesting for chlorine residual, checking chlorination equipment and searching for a source of contamination.

Answers to questions on page 193.

5.3A Contamination through cross-connections has consistently caused more waterborne disease outbreaks in the United States than any other reported factor.

5.3B Responsibilities in the implementation of cross-connection control programs are shared by water suppliers, water users, health agencies, and plumbing officials.

5.3C The water user's cross-connection control responsibility is to keep contaminants out of the potable water system on the user's premises. The user also has the responsibility to prevent the creation of cross-connections through modifications of the plumbing system on the premises.

Answers to questions on page 196.

5.3D Items that should be included on a cross-connection survey form include (1) location, (2) date, (3) names of investigator(s) and building representative(s), (4) water source(s), (5) piping system(s), (6) points of interconnection, (7) special equipment, and (8) remarks or recommendations.

5.3E Factors that should be considered when selecting a backflow prevention device include the (1) degree of hazard, (2) probability of backflow occurring, and (3) complexity of the piping on the premises and the probability of its modification.

5.3F Air gap or reduced pressure principle backflow prevention devices are installed at wastewater treatment plants, wastewater pumping stations, reclaimed water reuse areas, areas where toxic substances in toxic concentrations are handled under pressure, premises having an auxiliary water supply which is or may be contaminated, and in locations where fertilizer, herbicides or pesticides are injected into a sprinkler system.

Answers to questions on page 201.

5.4A Distribution systems should always be under a continuous positive pressure at all times to meet the needs of the customers and to prevent contamination from backflow.

5.4B Excessive distribution system pressures could cause damage to water-using facilities and unintentional higher water use.

5.4C Possible causes of low water distribution system pressures include pipes being too small or velocities being too high as a result of excessive demands by consumers, fires, or leaks; improperly adjusted valves; and blocked regulator screens.

Answers to questions on page 201.

5.5A The main function of a distribution storage reservoir is to meet daily water demands as well as peak demands.

5.5B Distribution system reservoirs should be full at the start of the peak demand period.

Answers to questions on page 203.

5.6A Pump alignment procedures are critical because there should be no strain on the pump case from the suction and discharge piping connections.

5.6B Important pump inspection and preventive maintenance procedures include:

1. Observe and record pump pressures and output (flow), and current demands,
2. Make visual checks for excessive or abnormal noise, vibration, heat and odor,
3. Provide necessary grease and oil lubrication,
4. Check bearing temperatures,
5. Listen for any bearing noise,
6. Tighten packing glands if leaking excessively,
7. Inspect priming system,
8. Routinely operate internal combustion-driven pumps and generators on standby, and
9. Check pump alignment.

5.6C Bearings should be checked for temperature, noise and proper lubrication.

5.6D New pump packing rings should be installed when the packing is worn or compressed so that the gland cannot be tightened farther.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 204.

5.70A Types of pipe maintenance performed by distribution system operators include repairing, flushing, cleaning, disinfecting and relining.

5.70B Pipes deteriorate on the inside because of water corrosion and erosion and on the outside due to corrosion from aggressive soil moisture.

Answers to questions on page 207.

5.70C Most leaks originate from a weakened joint or fitting connection or from a damaged or corroded part of a pipe.

5.70D A probe is a sharp-pointed metal rod that is thrust into the ground and then pulled up for inspection. If the rod is moist or muddy, the line of the leak is being followed.

5.70E Waste control studies are usually conducted when no specific reason can be found for a significant water loss in the system.

Answers to questions on page 208.

5.70F Buried pipes may have to be located to find leaks, to make a new connection, or if excavation must be made in the area to locate or install other facilities.

5.70G Buried non-metallic pipes can be located by (1) driving stainless steel tipped shafts into the ground until they hit the pipe, and (2) placing a tracer tape which is detectable by electronic finders on top of the pipe before it is covered.

5.70H A leak in a wall of a pipe can be repaired by using a repair clamp. Repair clamps are short, cylindrical pieces usually made into two halves and bolted together or otherwise fastened around the leaking spot.

Answers to questions on page 215.

5.70I Wet tapping is a procedure for making a service connection while the water main is under pressure.

5.70J Pressure surveys are conducted in a water distribution system to indicate the hydraulic efficiency of the system in meeting normal requirements.

5.70K A pressure record covering a long period of time at one location can be obtained by using a recording pressure gage. The gage is connected to some type of recorder such as a strip chart.

Answers to questions on page 219.

5.70L The frequency of routine flushing can usually be determined by customer complaints and the types of material found during the flushing procedure.

5.70M Valves should be closed slowly during a flushing operation to prevent water hammer.

5.70N Information that should be recorded during a flushing operation includes date, time, location, pressure zone, size of main (diameter, length), flushing rate (GPM), flush velocity (ft/sec), and description of the flushed water (appearance and odor).

Answers to questions on page 224.

5.70O Foam swabs are efficient in removing loose sediments, soft scales and slimes from water mains.

5.70P The entry and exit points for foam swabs and pigs in a small water main are fire hydrants, air valves, blowoffs, wyes and tees.

5.70Q The recommended speed for a swab cleaning a water main is 2 to 4 feet per second.

5.70R After a water main is cleaned with a swab, the main should be flushed and disinfected (chlorinated). When the main is reactivated, services should be flushed and any temporary services removed.

Answers to questions on page 226.

5.70S Water mains are cement lined to prevent corrosion and tuberculation; to increase capacity, improve water quality and to reduce leakage through poor joints and holes.

5.70T Metal water mains must be inspected on the outside before considering cement-mortar lining to be sure outside corrosion is not so bad that the mains must be replaced.

5.70U The inside of water mains are inspected before a lining job by the use of a TV camera, by crawling through the main or by being pulled through on a sled.

Answers to questions on page 240.

5.70V Freezing problems with service lines are usually greater than with mains because service lines have less ground cover over them and are smaller.

5.70W Frozen water mains can be thawed by the use of electrical thawing methods, hot water or by blowing steam from a portable boiler into the frozen pipes.

5.70X When using electrical thawing methods, any electrical appliance that is grounded to the pipe should be disconnected during the thawing operation.

ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 245.

5.71A Water utilities can avoid serious valve problems by a comprehensive program of valve inspection, exercising and maintenance.

5.71B Operators must be able to find valves in order to shut off any valve at any time in case of a line break or other emergency.

5.71C Valves should be exercised to (1) determine whether or not the valve works, (2) extend valve life, and (3) help clean encrustation from the valve seats and gates.

5.71D A noisy or vibrating valve may be an indication that cavitation is occurring at a valve.

Answers to questions on page 246.

5.72A Hydrant suppliers can furnish operators with information on hydrant operation, maintenance, parts manuals and solving particular problems.

5.72B Fire hydrants should be inspected twice a year and after each use.

5.72C Fire hydrant inspection and maintenance procedures include:

1. Inspect for leakage and make corrections when found,
2. Open hydrant fully, checking for ease of operation,
3. Flush hydrant,
4. Inspect, clean and lubricate threads,
5. Replace caps, but not too tight,
6. Check for any exterior obstructions,
7. Check dry-barrel hydrants for drainage,
8. Clean exterior of hydrant and repaint if necessary,
9. Be sure auxiliary valve is fully open,
10. Tag inoperable hydrants, and
11. Record inspection, maintenance and repair work performed.

5.72D If a dry-barrel hydrant is operated when the valve is not fully opened, the drain will be partially open. Water will seep through the drain, saturate the drain field and could result in hydrant damage due to freezing.

Answers to questions on page 249.

5.73A A meter testing program should be based on meter use, water quality, age of meter, cost of testing, and water rates. The potential revenue loss from inaccurate meters must also be considered.

5.73B Most modern water meters have sealed registers and easily changed measuring chambers. These meters are usually maintained and repaired by the utility.

5.73C Meter registers may be mechanically or magnetically driven.

Answers to questions on page 250.

5.73D Inaccurate meter registration results from wear, corrosion and deposition.

5.73E Meter maintenance and repair consists essentially of dismantling and thoroughly cleaning the meter and inspecting all of its parts. The main procedures are:

1. Remove meter from service and take to shop,
2. Dismantle the meter,
3. Inspect the various parts of the meter for excessive wear and corrosion, pitting or distortion,
4. Replace all defective and badly worn parts,
5. Thoroughly clean all parts to be used,
6. Assure that the gear train (if any) runs freely,
7. Check the action of the disc in the chamber of the main casing before and after assembly,
8. Use a new meter as a comparison standard for tolerances and clearances, and
9. Retest the meter for accuracy.

5.73F The correct reading for the meter shown in Figure 8.44 is 2,697,491 cu ft.

Answers to questions on page 252.

5.74A Water main breaks can be caused by traffic accidents, earthquakes or washouts.

5.74B After the valves are closed, the hole where the break is located can be drained by the use of a trash pump.

5.75A Coupons are steel specimens inserted in water mains to indicate the rate of corrosion of metal pipe. By weighing the specimens, the loss of weight over time is a measure of the corrosion rate.

ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 254.

5.8A Distribution system mains and reservoirs should be disinfected to prevent waterborne-disease outbreaks with the utility agency being legally liable.

5.8B The three forms of chlorine available for disinfecting a water main are (1) liquid chlorine, (2) sodium hypochlorite, and (3) calcium hypochlorite.

5.8C When using tablets to disinfect a water main, the chlorinated water should remain in the line for at least 24 hours.

5.8D When the disinfection procedures for a water main are completed, bacteriological samples are collected.

Answers to questions on page 256.

5.8E Distribution system storage facilities should be disinfected before being placed in or returned to service, when they are newly installed, or when they are taken out of service for any reason and the circumstances are such that there could be contamination of water.

5.8F The interior surfaces of a storage facility are cleaned before disinfection by first removing all materials not belonging in the empty tank. Then all interior surfaces of the facility are cleaned thoroughly using a high pressure water jet, scrubbing, sweeping, or some equivalent method.

5.8G The free chlorine residual in the water can be reduced to less than 2 mg/*L* by (1) completely draining and refilling the facility, (2) having additional holding time and blending with potable water having a low chlorine concentration, or (3) by the addition of reducing chemicals to neutralize the chlorine.

5.8H Reducing agents that could be used to neutralize a free chlorine residual include sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), and sodium thiosulfite ($Na_2S_2O_3 \cdot 5H_2O$).

Answers to questions on page 260.

5.9A If good records are not kept, operators may not know the construction details of important facilities, where they are located, or what shape they are in. Also the utility may lose damage suits because of poor records.

5.9B The comprehensive map provides an overview of the entire distribution system.

5.9C Whenever changes or modifications are made, the "as built" plans should be changed to show the details of the modification, the date of the modification, and who recorded the modification on the plans.

5.9D Valve and hydrant maps show valve and hydrant locations, the direction to open the valve, the number of turns to open, the model type and the installation date.

Answers to questions on page 263.

5.10A Factors that should be considered when selecting tools and equipment for distribution system operation and maintenance include:

1. Cost and efficiency (including any reduction in labor costs),
2. Reduction of duration of service interruptions,
3. Ability to make the job easier for the operators (a morale factor), and
4. Versatility of tools or equipment for use in different types of operation and maintenance jobs.

5.10B Physical inventories should be made once or twice a year.

Answers to questions on page 265.

5.11A Utilities should develop plans for the following routine disruptions of service:

1. A key water main breaks,
2. An extended electrical power interruption occurs,
3. A vitally needed well pump motor or bearing "burns out,"
4. A key chlorinator or treatment unit fails, and
5. Test results or direct observations indicate the water supply has become contaminated.

5.11B An Emergency Operations Plan has been defined simply as: "Under disaster conditions, *WHO* does *WHAT*, and *WHEN* with the existing resources."

5.11C The three basic steps of an emergency operations plan are:

1. Priorities by which the requirements can be met are specified,
2. The best ways of using available resources are designated, and
3. Specific tasks are determined and are assigned to the assumed surviving or available personnel.

Answers to questions on page 269.

5.12A The operator should present to the public the image of a neat, efficient, knowledgeable, and cooperative individual.

5.12B To determine the cause of a customer's complaint regarding low pressures:

1. Take pressure readings in the customer's house without any flow (taps closed) so as to obtain the approximate system pressure, and
2. Turn on the taps in the house and take another pressure reading.

A drop in pressure readings could indicate plumbing problems in the house.

Answers to questions on page 270.

5.13A Weed seeds get into a lawn from the soil, lawn seeds, birds and the wind.

5.13B A lawn needs nitrogen if it turns yellow or pale green or if the grass becomes thin and weeds start growing.

OBJECTIVE TEST

CHAPTER 5. DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True-False

1. The National Secondary Drinking Water Regulations are federally enforceable.
    1. True
    2. False
2. Reservoir covers should be water tight.
    1. True
    2. False
3. Vacuum valves in vaults should be inspected after rains.
    1. True
    2. False
4. If you discover a vandal who refuses to leave a facility, physically removal the vandal.
    1. True
    2. False
5. The water quality monitoring requirements established by the U.S. Environmental Protection Agency specify the maximum number of samples required.
    1. True
    2. False
6. The best evaluation of water quality can be obtained from samples drawn direct from a household faucet.
    1. True
    2. False
7. Pump packing glands should be tightened to the point where there is no leakage.
    1. True
    2. False
8. Meters tend to over-register the amount of water used as they get older.
    1. True
    2. False
9. The most convenient flow measuring device for waste control studies is the venturi meter.
    1. True
    2. False
10. Backflow of contaminated water through cross-connections into community water systems is a serious problem.
    1. True
    2. False
11. Proper pump alignment will prevent strain on the pump shaft.
    1. True
    2. False
12. Pump inspection schedules are often based on the gallons of water pumped since the last inspection.
    1. True
    2. False
13. A flushing program should start at the far ends of the distribution system and work towards the source.
    1. True
    2. False
14. Pressure gages must be tested and recalibrated frequently to insure accurate readings.
    1. True
    2. False
15. Hypochlorite should be stored in a cool, dark location and used as soon as possible.
    1. True
    2. False
16. Water storage facilities must be cleaned before disinfection is started.
    1. True
    2. False
17. Field testing of meters is usually done only to meters smaller than two inches.
    1. True
    2. False
18. Most distribution system valves suffer from lack of operation rather than wear.
    1. True
    2. False
19. Chlorine tablets are best suited for disinfecting large diameter water mains.
    1. True
    2. False
20. Many water utilities are installing remote-reading customer meters.
    1. True
    2. False
21. The use of swabs to clean a main is more likely to result in leaks at a later date than the use of pigs.
    1. True
    2. False
22. Cleaning is a permanent solution to water main problems.
    1. True
    2. False

23. Each valve should have a permanent valve record file card or computer file.
    1. True
    2. False
24. The first step in preparing for a disaster is to form a disaster organization.
    1. True
    2. False
25. Every employee of a utility is responsible for customer relations and for positive customer communication.
    1. True
    2. False

Multiple Choice

26. Commonly used methods for determining the condition of the inside of a pipe include
    1. Inspecting pipe cut-outs from tapping operations.
    2. Looking during repairs or additions to the system.
    3. Measuring the C Factor.
    4. Periodically draining pipe, opening a valve and looking inside.
    5. Placing coupons in the distribution system.
27. During inspections of water supply reservoirs, the water quality should be observed for any changes in
    1. Alkalinity.
    2. Coliforms.
    3. Color.
    4. Odor.
    5. Turbidity.
28. Items that may be found during the inspection of a potable water storage reservoir include
    1. Birds.
    2. Bottles.
    3. Cans.
    4. Paper.
    5. Rodents.
29. Water distribution system surveillance programs include attention to
    1. Emergency planning.
    2. Equipment and stores.
    3. Storm damage.
    4. Valves.
    5. Vandalism.
30. The U.S. Environmental Protection Agency requires _______ samples for total trihalomethanes per water treatment plant every three months.
    1. 1
    2. 2
    3. 3
    4. 4
    5. 12
31. Water quality monitoring is done to
    1. Calibrate laboratory instruments.
    2. Detect any changes in water quality between the source and the distribution system.
    3. Establish the safety and potability of the supply.
    4. Help determine the source of any contaminants that reach the system.
    5. Provide a record of the quality of the water served.
32. Backflow prevention devices approved for installation at reclaimed water reuse areas include
    1. Air-gap separation devices.
    2. Atmospheric vacuum breaker devices.
    3. Double check valve devices.
    4. Pressure vacuum breaker devices.
    5. Reduced pressure principle devices.
33. Approved backflow prevention devices include
    1. Air-gap separation devices.
    2. Corporation stop devices.
    3. Curb stop devices.
    4. Double check valve devices.
    5. Reduced pressure principle devices.
34. Pipe deterioration may be revealed by
    1. Degradation of water quality.
    2. Increases in C Factor.
    3. Increases in system pressures.
    4. Leaks.
    5. Loss of water carrying capacities.
35. Factors commonly sensed by automatic pumping controls include
    1. Desirable water elevation at start of day.
    2. Quantity of water needed in storage at various times.
    3. Quantity of water pumped.
    4. Water elevation.
    5. Water pressure.
36. Results obtained from pipe roughness coefficient tests can indicate whether or not
    1. Contamination is entering the pipe.
    2. Friction losses in the pipe are increasing.
    3. The ability of the pipe to transmit water is being hindered.
    4. The quality of the water in the pipe is deteriorating.
    5. The size and number of leaks are increasing.
37. The amount of unaccounted for water is affected by
    1. Demands for water.
    2. Leakage reduction programs.
    3. Meter accuracy.
    4. Pressures.
    5. Unauthorized use of water.
38. Leaks from pipes may be detected by
    1. Direct observation.
    2. Listening devices.
    3. Measuring the water running from a leak.
    4. Probes.
    5. Waste control studies.
39. Loss of water carrying capacity in a pipe may result from
    1. Corrosion.
    2. Pitting.
    3. Sediment.
    4. Slime growth.
    5. Tuberculation.
40. Water mains are cement lined to
    1. Improve structural strength.
    2. Increase carrying capacity.
    3. Prevent corrosion.
    4. Prevent release of corrosion products into water.
    5. Reduce leakage through poor joints.

41. The purpose of flushing water distribution lines is to
    1. Avoid taste and odor complaints.
    2. Clean out lines.
    3. Control corrosion.
    4. Locate leaks.
    5. Remove sediment.

42. Valves must be exercised at least once a
    1. Week.
    2. Month.
    3. Quarter.
    4. Half year.
    5. Year.

43. Which of the following tasks should be conducted during a routine valve inspection?
    1. Determine accuracy of valve locations on system map
    2. Inspect valve for damage or leakage
    3. Practice closing valves as quickly as possible in case an emergency arises
    4. Record minimum time for closing valve during an emergency
    5. Record number of turns to fully open or close a valve

44. How frequently should small meters be tested?
    1. Once a year
    2. 1-2 years
    3. 2-4 years
    4. 3-5 years
    5. 5-10 years

45. How often should fire hydrants be inspected and maintained?
    1. Weekly
    2. Monthly
    3. Quarterly
    4. Twice a year
    5. Annually

46. Disaster plans should be developed in case of
    1. Broken mains.
    2. Earthquakes.
    3. Floods.
    4. Power outages.
    5. Pump stoppages.

47. The Primary Drinking Water Regulations require each public water system to maintain records of
    1. Actions taken to correct violations.
    2. "As built" plans.
    3. Consumer complaints.
    4. Variances or exemptions.
    5. Water quality analyses.

48. What information should be shown on comprehensive maps?
    1. Hydrants
    2. Mains
    3. Reservoirs
    4. Valves
    5. Wells

49. When should distribution system mains and storage facilities be disinfected?
    1. Before being placed in service
    2. Before being returned to service
    3. On a routine basis after being in service for a specified time period
    4. When they are new
    5. Whenever there could be contamination of the water

50. How does an operator communicate with a water utility's customers?
    1. Answering complaints
    2. Driving recklessly
    3. Flushing lines
    4. Painting fire hydrants
    5. Repairing lines

51. Causes of electric motors overheating include
    1. Clogged ventilation.
    2. Excessively hot weather.
    3. Locked rotor.
    4. Overloading.
    5. Rapid cycling.

52. A 10-inch water main is to be flushed at a velocity of 6 ft/sec. What should be the reading on the flow meter in gallons per minute?
    1. 150 GPM
    2. 940 GPM
    3. 1,470 GPM
    4. 1,640 GPM
    5. 2,110 GPM

53. During a test of a totalizing flow meter, the water depth rose 42 inches in a volumetric tank 45 inches in diameter. What was the total flow in gallons?
    1. 77 gallons
    2. 289 gallons
    3. 302 gallons
    4. 322 gallons
    5. 3,470 gallons

54. Estimate the flow from a pipe in gallons per minute if a 55-gallon drum fills in 9 minutes and 36 seconds.
    1. 4.0 GPM
    2. 5.5 GPM
    3. 5.7 GPM
    4. 5.9 GPM
    5. 6.7 GPM

55. A water meter is tested in a laboratory. The meter reads 93 gallons. The actual flow was measured in a volumetric tank as 95 gallons. Determine the meter accuracy as a percentage.
    1. 97.9%
    2. 98.3%
    3. 98.7%
    4. 101.5%
    5. 102.2%

56. A trench 4.5-feet wide, 870-feet long and 6.5-feet deep is to be excavated for a water main. How many cubic yards of soil must be excavated for the water main?
    1. 177 cu yd
    2. 607 cu yd
    3. 845 cu yd
    4. 943 cu yd
    5. 2,545 cu yd

57. A flow meter indicates a flow of 115 GPM. How long will it take to fill a 20,000 gallon storage tank?
    1. 1 hr 45 min
    2. 2 hr 27 min
    3. 2 hr 54 min
    4. 3 hr 20 min
    5. 3 hr 33 min

58. What horsepower must a pump deliver to water which must be lifted 130 feet when the flow is 175 GPM?
    1. 4.24 HP
    2. 5.75 HP
    3. 6.19 HP
    4. 8.48 HP
    5. 11.50 HP

59. How many kilowatt-hours per day are required by a pump with a motor input horsepower of 75 horsepower when the pump operates 24 hours per day?
    1. 1,164 KWH/day
    2. 1,343 KWH/day
    3. 1,732 KWH/day
    4. 1,800 KWH/day
    5. 2,091 KWH/day

60. What is the wire-to-water efficiency of a pump if the water horsepower is 50 horsepower and the electrical power input is 80 horsepower?
    1. 51%
    2. 57%
    3. 63%
    4. 75%
    5. 89%

End of Objective Test

CHAPTER 6

DISINFECTION

by

Tom Ikesaki

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OBJECTIVES

Chapter 6. DISINFECTION

Following completion of Chapter 6, you should be able to:

1. Disinfect new and existing wells,
2. Disinfect mains,
3. Calculate chlorine dosage,
4. Determine hypochlorinator and chlorinator settings,
5. Operate and maintain hypochlorinators,
6. Operate and maintain chlorinators,
7. Troubleshoot chlorination systems, and
8. Conduct a chlorine safety program.

GLOSSARY

Chapter 6. DISINFECTION

AMPEROMETRIC (am-PURR-o-MET-rick) AMPEROMETRIC

Based on the electric current that flows between two electrodes in a solution.

AMPEROMETRIC TITRATION (am-PURR-o-MET-rick) AMPEROMETRIC TITRATION

A means of measuring concentrations of certain substances in water (such as strong oxidizers) based on the electric current that flows during a chemical reaction.

BACTERIA (back-TEER-e-uh) BACTERIA

Bacteria are living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BREAKPOINT CHLORINATION BREAKPOINT CHLORINATION

Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

CARCINOGEN (car-SIN-o-jen) CARCINOGEN

Any substance which tends to produce a cancer in an organism.

CHLORAMINES (KLOR-uh-means) CHLORAMINES

Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.

CHLORINATION (KLOR-uh-NAY-shun) CHLORINATION

The application of chlorine to water, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results (aiding coagulation and controlling tastes and odors).

CHLORINE DEMAND CHLORINE DEMAND

Chlorine demand is the difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

Chlorine Demand, mg/*L* = Chlorine Demand, mg/*L* − Chlorine Residual, mg/*L*

CHLORINE REQUIREMENT CHLORINE REQUIREMENT

The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or oxidizing some substance in the water. In each case a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CHLORORGANIC (klor-or-GAN-ick) CHLORORGANIC

Organic compounds combined with chlorine. These compounds generally originate from, or are associated with, life processes such as those of algae in water.

CHLOROPHENOLIC (klor-o-FEE-NO-lick) CHLOROPHENOLIC

Chlorophenolic compounds are phenolic compounds (carbolic acid) combined with chlorine.

COLIFORM (COAL-i-form) COLIFORM

A group of bacteria which are found in the intestine of warm blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.

COLORIMETRIC MEASUREMENT COLORIMETRIC MEASUREMENT

A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity. The specific color of the sample, developed by addition of chemical reagents, is measured with a photoelectric colorimeter or is compared with "color standards" using, or corresponding with, known concentrations of the chemical.

COMBINED AVAILABLE RESIDUAL CHLORINE COMBINED AVAILABLE RESIDUAL CHLORINE

The concentration of residual chlorine which is combined with ammonia (NH_3) and/or organic nitrogen in water as a chloramine (or other chloro derivatives) yet is still available to oxidize organic matter and utilize its bactericidal properties.

COMBINED RESIDUAL CHLORINATION COMBINED RESIDUAL CHLORINATION

The application of chlorine to water to produce a combined available residual chlorine. The residual can be made up of monochloramines, dichloramines, and nitrogen trichloride.

DISINFECTION (dis-in-FECK-shun) DISINFECTION

The process designed to kill most microorganisms in water, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water treatment. Compare with STERILIZATION.

DPD (pronounced as separate letters) DPD

A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. DPD stands for N, N-diethyl-p-phenylene-diamine.

EDUCTOR (e-DUCK-ter) EDUCTOR

A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump. As an injector, it is used to produce vacuum for chlorinators.

ENTERIC ENTERIC

Of intestinal origin, especially applied to wastes or bacteria.

ENZYMES (EN-zimes) ENZYMES

Organic substances (produced by living organisms) which cause or speed up chemical reactions. Organic catalysts and/or biological catalysts.

FREE AVAILABLE RESIDUAL CHLORINE FREE AVAILABLE RESIDUAL CHLORINE

That portion of the total available residual chlorine composed of dissolved chlorine gas (Cl_2), hypochlorous acid (HOCl), and/or hypochlorite ion (OCl^-) remaining in water after chlorination. This does not include chlorine that has combined with ammonia, nitrogen, or other compounds.

HEPATITIS (HEP-uh-TIE-tis) HEPATITIS

Hepatitis is an inflammation of the liver usually caused by an acute viral infection. Yellow jaundice is one symptom of hepatitis.

HTH (pronounce as separate letters) HTH

High **T**est **H**ypochlorite. Calcium hypochlorite or $Ca(OCl)_2$.

HYDROLYSIS (hi-DROLL-uh-sis) HYDROLYSIS

A chemical reaction in which a compound is converted into another compound by taking up water.

HYPOCHLORINATION (hi-po-KLOR-uh-NAY-shun) HYPOCHLORINATION

The application of hypochlorite compounds to water for the purpose of disinfection.

HYPOCHLORITE (hi-po-KLOR-ite) HYPOCHLORITE

Chemical compounds containing available chlorine; used for disinfection. They are available as liquids (bleach) or solids (powder, granules and pellets). Salts of hypochlorous acid.

MPN (pronounce as separate letters) MPN

MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume of sample water. Expressed as the number of organisms per 100 m*L* of sample water.

NITROGENOUS (ny-TRAH-jen-us) NITROGENOUS

A term used to describe chemical compounds (usually organic) containing nitrogen in combined forms. Proteins and nitrates are nitrogenous compounds.

ORTHOTOLIDINE (or-tho-TOL-uh-dine) ORTHOTOLIDINE

Orthotolidine is a colorimetric indicator of chlorine residual. If chlorine is present, a yellow-colored compound is produced. This reagent is no longer approved for chemical analysis.

OXIDATION (ox-uh-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In the environment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

OXIDIZING AGENT OXIDIZING AGENT

Any substance, such as oxygen (O_2) and chlorine (Cl_2), that will readily add (take on) electrons. The opposite is a REDUCING AGENT.

PALATABLE (PAL-a-ta-ble) PALATABLE

Water at a desirable temperature that is free from objectionable tastes, odors, colors, and turbidity. Pleasing to the senses.

PATHOGENIC ORGANISMS (path-o-JEN-nick) PATHOGENIC ORGANISMS

Organisms, including bacteria, viruses or cysts capable of causing diseases (typhoid, cholera, dysentery) in a host (such as a person). There are many types of bacteria which do NOT cause disease. These organisms are called non-pathogenic.

PHENOLIC COMPOUNDS (FEE-noll-LICK) PHENOLIC COMPOUNDS

Organic compounds that are derivatives of benzene.

POSTCHLORINATION POSTCHLORINATION

The addition of chlorine to the plant effluent, *FOLLOWING* plant treatment, for disinfection purposes.

POTABLE WATER (POE-ta-bl) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

PRECHLORINATION PRECHLORINATION

The addition of chlorine at the headworks of the plant *PRIOR TO* other treatment processes mainly for disinfection and control of tastes, odors, and aquatic growths. Also applied to aid in coagulation and settling.

PRECURSOR, THM (pre-CURSE-or) PRECURSOR, THM

Natural organic compounds found in all surface and groundwaters. These compounds *MAY* react with halogens (such as chlorine) to form trihalomethanes (try-HAL-o-METH-hanes) (THMs); they *MUST* be present in order for THMs to form.

REAGENT (re-A-gent) REAGENT

A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances.

REDUCING AGENT REDUCING AGENT

Any substance, such as a base metal (iron) or the sulfide ion (S^{2-}), that will readily donate (give up) electrons. The opposite is an OXIDIZING AGENT.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions (no dissolved oxygen present), sulfur compounds are reduced to odor-producing hydrogen sulfide (H_2S) and other compounds. The opposite of OXIDATION.

RELIQUEFACTION (re-LICK-we-FACK-shun) RELIQUEFACTION

The return of a gas to the liquid state; for example, a condensation of chlorine gas to return it to its liquid form by cooling.

RESIDUAL CHLORINE RESIDUAL CHLORINE

The amount of free and/or available chlorine remaining after a given contact time under specified conditions.

ROTAMETER (RODE-uh-ME-ter) ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a tapered, calibrated tube. Inside the tube is a small ball or bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind or on the tube by looking at the middle of the ball or at the widest part of the float.

SAPROPHYTES (SAP-row-FIGHTS) SAPROPHYTES

Organisms living in dead or decaying organic matter. They help natural decomposition of the organic solids in water.

STERILIZATION (stare-uh-luh-ZAY-shun) STERILIZATION

The removal or destruction of all living microorganisms, including pathogenic and other bacteria, vegetative forms and spores. Compare with DISINFECTION.

TITRATE (TIE-trate) TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a certain color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical reagent in increments until completion of the reaction, as signaled by the end point.

TOTAL RESIDUAL CHLORINE TOTAL RESIDUAL CHLORINE

The amount of available chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see RESIDUAL CHLORINE.

TRIHALOMETHANES (TRI-HAL-o-METH-hanes) TRIHALOMETHANES

Derivatives of methane, CH_4, in which three halogen atoms (chlorine or bromine) are substituted for three hydrogen atoms. Often formed during chlorination by reactions with natural organic materials in the water. The resultant compounds (THMs) are suspected of causing cancer.

TURBIDITY (ter-BID-it-tee) TURBIDITY

The cloudy appearance of water caused by the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.

Chapter 6. DISINFECTION

(Lesson 1 of 2 Lessons)

6.0 PURPOSE OF DISINFECTION

6.00 Making Water Safe for Consumption

Our single most important natural resource is water. Without water we could not exist. Unfortunately, safe water is becoming very difficult to find. In the past, safe water could be found in remote areas, but with population growth and related pollution of waters, there are very few natural waters left that are safe to drink without treatment of some kind.

Water is the universal solvent and therefore carries all types of dissolved materials. Water also carries biological life forms which can cause diseases. These water-borne pathogenic organisms are listed in Table 6.1. Most of these organisms and the diseases they transmit are no longer a problem in the United States due to proper water protection, treatment and monitoring. However, many developing regions of the world still experience serious outbreaks of various water-borne diseases.

One of the cleansing processes in the treatment of safe water is called disinfection. Disinfection is the selective destruction of pathogenic organisms. Don't confuse disinfection with sterilization. Sterilization is the complete destruction of all organisms. Sterilization is not necessary in water treatment and is also quite expensive.

6.01 Safe Drinking Water Laws

In the United States, the U.S. Environmental Protection Agency is responsible for setting drinking water standards and for insuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce. The 1976 Primary Drinking Water Regulations contain specific maximum allowable levels of substances known to be hazardous to human health. In addition to describing maximum contaminant levels (MCLs), the 1976 Primary Drinking Water Regulations also give detailed instructions on what to do when you exceed the maximum contaminant level for a particular substance. In Table 6.2 you will find an example of the Primary Drinking Water Regulations for *COLIFORM*[1] bacteria which are supposed to be killed by disinfection. Table 6.3 lists the coliform samples required per population served.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.0A What are pathogenic organisms?

6.0B What is disinfection?

6.0C Drinking water standards are established by what agency of the United States government?

6.0D MCL stands for what words?

TABLE 6.1 PATHOGENIC ORGANISMS (DISEASES) TRANSMITTED BY WATER

Bacteria
- Salmonella (salmonellosis)
- Shigella (bacillary dysentery)
- Bacillus typhosus (typhoid fever)
- Salmonella paratyphi (paratyphoid)
- Vibrio cholerae (cholera)

Viruses
- Enterovirus
  - Poliovirus
  - Coxsackie Virus
  - Echo Virus
- Andenovirus
- Reovirus
- Infectious Hepatitis

Intestinal Parasites
- Entamoeba histolytica (amoebic dysentery)
- Giardia lamblia (giardiasis)
- Ascaris lumbricoides (giant roundworm)

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[1] *Coliform (COAL-i-form). A group of bacteria which are found in the intestine of warm blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.*

TABLE 6.2 MICROBIOLOGICAL STANDARDS[a]

Contaminant	Maximum Contaminant Level (MCL)	Monitoring Requirement — Surface Only or Combination	Check Sampling, Reporting, and Public Notice
Coliform Bacteria[b]	*MEMBRANE FILTER* Coliforms shall not exceed: 1 per 100 mL, mean of all samples per month, 4 per 100 mL in more than one sample if less than 20 samples collected per month, or, 4 per 100 mL in more than 5% of samples if 20 or more samples are examined per month. *FERMENTATION TUBE — 10 mL PORTION* Coliforms shall not be present in more than 10% of portions per month, Not more than 1 sample may have 3 or more portions positive when less than 20 samples are examined per month, or Not more than 5% of samples may have 3 or more portions positive when 20 or more samples are examined per month.	Regular time intervals, monthly rate based on population (Table 9.3).	If MCL is exceeded, report to state within 48 hours and notify public. *MEMBRANE FILTER* If a single sample exceeds 4 per 100 mL, initiate at least two consecutive daily check samples from one sampling point. Collect additional samples daily or as directed by the state until at least two consecutive daily check samples show less than 1 per 100 mL. If any check sample confirms the presence of coliform, report to the state within 48 hours. *FERMENTATION TUBE* If a single sample contains coliform in 3 or more 10 mL portions, initiate check sampling as above and continue until at least two consecutive daily check samples show no positive tubes. If any check sample confirms the presence of coliform report to state within 48 hours.

[a] See Chapter 22, "Drinking Water Regulations," and poster provided with this manual for more details.

[b] See Chapter 7, "Laboratory Procedures," *SMALL WATER SYSTEM OPERATION AND MAINTENANCE*, for details on how to do the coliform bacteria tests (membrane filter (MF) and multiple-tube fermentation (MPN)).

6.1 FACTORS INFLUENCING DISINFECTION

6.10 pH

The pH of water being treated can alter the efficiency of disinfectants. Chlorine, for example, disinfects water much faster at a pH around 7.0 than at a pH over 8.0.

6.11 Temperature

Temperature conditions also influence the effectiveness of the disinfectant. The higher the temperature of the water, the more efficiently it can be treated. Water near 70 to 85°F (21 to 29°C) is easier to disinfect than water at 40 to 60°F (4 to 16°C). Longer contact times are required to disinfect water at lower temperatures. To speed up the process, operators often simply use larger amounts of chemicals. Where water is exposed to the atmosphere, the warmer the water temperature the greater the dissipation rate of chlorine into the atmosphere.

6.12 Turbidity

Under normal operating conditions, the turbidity level of water being treated is very low by the time the water reaches the disinfection process. Excessive turbidity will greatly reduce the efficiency of the disinfecting chemical or process. Studies in water treatment plants have shown that when water is filtered to a turbidity of one unit or less, most of the bacteria have been removed.

The suspended matter itself may also change the chemical nature of the water when the disinfectant is added. Some types of suspended solids can create a continuing demand for the chemical, thus changing the effective germicidal (germ killing) properties of the disinfectant.

6.120 Organic Matter

Organics found in the water can consume great amounts of disinfectants while forming unwanted compounds. *TRIHALOMETHANES*[2] are an example of undesirable compounds formed by reactions between chlorine and certain organics. Disinfecting chemicals often react with organics and *REDUCING AGENTS*[3] (Section 6.13). Then, if any of the chemical remains available after this initial reaction, it can act as an effective disinfectant. The reactions with organics and reducing agents, however, will have significantly reduced the amount of chemical available for this purpose.

6.121 Inorganic Matter

Inorganic compounds such as ammonia (NH_3) in the water being treated can create special problems. In the presence of ammonia, some oxidizing chemicals form side com-

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[2] *Trihalomethanes (TRI-HAL-o-METH-hanes). Derivatives of methane, CH_4, in which three halogen atoms (chlorine or bromine) are substituted for three hydrogen atoms. Often formed during chlorination by reactions with natural organic materials in the water. The resultant compounds (THMs) are suspected of causing cancer.*

[3] *Reducing Agent. Any substance, such as a base metal (iron) or the sulfide ion (S^{2-}), that will easily donate (give up) electrons. The opposite is an oxidizing agent.*

TABLE 6.3 COLIFORM SAMPLES REQUIRED PER POPULATION SERVED

Population Served	Minimum Number of Samples per Month
25 to 1,000	1†
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19,800	22
19,801 to 20,700	23
20,701 to 21,500	24
21,501 to 22,300	25
22,301 to 23,200	26
23,201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30
28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46,001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,001 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170
320,001 to 360,000	180
360,001 to 410,000	190
410,001 to 450,000	200
450,001 to 500,000	210
500,001 to 550,000	220
550,001 to 600,000	230
600,001 to 660,000	240
660,001 to 720,000	250
720,001 to 780,000	260
780,001 to 840,000	270
840,001 to 910,000	280
910,001 to 970,000	290
970,001 to 1,050,000	300
1,050,001 to 1,140,000	310
1,140,001 to 1,230,000	320
1,230,001 to 1,320,000	330
1,320,001 to 1,420,000	340
1,420,001 to 1,520,000	350
1,520,001 to 1,630,000	360
1,630,001 to 1,730,000	370
1,730,001 to 1,850,000	380
1,850,001 to 1,970,000	390
1,970,001 to 2,060,000	400
2,060,001 to 2,270,000	410
2,270,001 to 2,510,000	420
2,510,001 to 2,750,000	430
2,750,001 to 3,020,000	440
3,020,001 to 3,320,000	450
3,320,001 to 3,620,000	460
3,620,001 to 3,960,000	470
3,960,001 to 4,310,000	480
4,310,001 to 4,690,000	490
More than 4,690,001	500

Source: EPA

† A community water system serving 25 to 1,000 persons, with written permission from the state, may reduce this sampling frequency, except that in no case shall it be reduced to less than one per quarter. The decision by the state will be based on a history of no coliform bacterial contamination for that system and on a sanitary survey by the state showing the water system to be supplied solely by a protected groundwater source; free of sanitary defects.

pounds causing a partial loss of disinfecting power. Silt can also create a chemical demand. It is clear, then, that the chemical properties of the water being treated can seriously interfere with the effectiveness of disinfecting chemicals.

6.13 Reducing Agents

Chlorine combines with a wide variety of materials, especially reducing agents. Most of the reactions are very rapid, while others are much slower. These side reactions complicate the use of chlorine for disinfection. The demand for chlorine by reducing agents must be satisfied before chlorine becomes available to accomplish disinfection. Examples of inorganic reducing agents present in water which will react with chlorine include hydrogen sulfide (H_2S), ferrous ion (Fe^{2+}), manganous ion (Mn^{2+}), and the nitrite ion (NO_2^-). Organic reducing agents in water also will react with chlorine and form chlorinated organic materials of potential health significance.

6.14 Microorganisms

6.140 Number and Types of Microorganisms

Microorganism concentration is important because the higher the number of microorganisms, the greater the demand for a disinfecting chemical. The resistance of microorganisms to specific disinfectants varies greatly. Non-spore-forming bacteria are generally less resistant than spore-forming bacteria. Cysts and viruses can be very resistant to certain types of disinfectants.

6.141 Removal Processes

Pathogenic organisms can be removed from water or killed by various physical and chemical water treatment processes. These processes are:

1. *COAGULATION.* Chemical coagulation followed by sedimentation and filtration will remove 90 to 95 percent of the pathogenic organisms, depending on which chemicals are used. Alum usage can increase virus removals up to 99 percent.
2. *SEDIMENTATION.* Properly designed sedimentation processes can effectively remove 20 to 70 percent of the pathogenic microrganisms. This removal is accomplished by allowing the pathogenic organisms (as well as nonpathogenic organisms) to settle out by gravity, assisted by chemical floc.
3. *FILTRATION.* Filtering water through granular filters is an effective means of removing pathogenic and other organisms from water. The removal rates vary from 20 to 99+ percent depending on the coarseness of the filter media and the type and effectiveness of pretreatment.
4. *DISINFECTION.* Disinfection chemicals such as chlorine are added to water to kill pathogenic microorganisms.

In chapter 4 you have studied the first three processes. The fourth, disinfection, is the subject of this chapter.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.1A How does temperature of the water influence disinfection?

6.1B How does pH influence the effectiveness of disinfection?

6.1C What influence do microorganisms have on disinfection?

6.2 PROCESS OF DISINFECTION

6.20 Purpose of Process

The purpose of disinfection is to destroy harmful organisms. This can be accomplished either physically or chemically. Physical methods may (1) physically remove the organisms from the water or (2) introduce motion that will disrupt the cells' biological activity and kill them.

Chemical methods alter the cell chemistry causing the microorganism to die. The most widely used disinfectant chemical is chlorine. Chlorine is easily obtained, relatively cheap, and most importantly, leaves a *RESIDUAL CHLORINE*[4] that can be measured. Other disinfectants are also used. There has been increased interest in disinfectants other than chlorine because of the *CARCINOGENIC*[5] compounds that chlorine may form (TRIHALOMETHANES or THMs).

This chapter will focus primarily on the use of chlorine as a disinfectant. However, let's take a brief look first at other disinfectant methods and chemicals. Some of these are being more widely applied today because of the potential adverse side effects of chlorination.

6.21 Agents of Disinfection

6.210 Physical Means of Disinfection

A. *ULTRAVIOLET RAYS* can be used to destroy pathogenic microorganisms. To be effective, the rays must come in contact with each microorganism. The ultraviolet energy disrupts various organic components of the cell causing a biological change that is fatal to the microorganisms.

This system has not had widespread acceptance because of the lack of measurable residual and the cost of operation. Currently, use of ultraviolet rays is limited to small or local systems and industrial applications. Ocean-going ships have used these systems for their water supply.

B. *HEAT* has been used for centuries to disinfect water. Boiling water for about 15 minutes will destroy essentially all microorganisms. This method is very energy intensive and thus very expensive. The only practical application is in the event of a disaster when individual local users are required to boil their water.

C. *ULTRASONIC WAVES* have been used to disinfect water on a very limited scale. Sonic waves destroy the microorganism by vibration. This procedure is not yet practical and is very expensive.

6.211 Chemical Disinfectants (Other Than Chlorine)

A. *IODINE* has been used as a disinfectant in water since 1920, but its use has been limited to emergency treatment of water supplies. Although it has long been recognized as a good disinfectant, iodine's high cost and potential physiological effects (pregnant women can suffer serious side effects) have prevented widespread acceptance. The recommended dosage is two drops of iodine (tincture of iodine which is 7 percent available iodine) in a liter of water.

B. *BROMINE* has been used only on a very limited scale for water treatment because of its handling difficulties. Bromine causes skin burns on contact. Because bromine is a very reactive chemical, residuals are hard to obtain. This also limits its use. Bromine can be purchased at swimming pool supply stores.

C. *BASES* such as sodium hydroxide and lime can be effective disinfectants but the high pH leaves a bitter taste in the finished water. Bases can also cause skin burns when left too long in contact with the skin. Bases effectively kill all microorganisms (they sterilize rather than just disinfect water). Although this method has not been used on a large scale, bases have been used to sterilize water pipes.

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[4] *Residual Chlorine. The amount of free and/or available chlorine remaining after a given contact time under specified conditions.*

[5] *Carcinogen (car-SIN-o-jen). Any substance which tends to produce a cancer in an organism.*

D. *OZONE* has been used in the water industry since the early 1900s, particularly in France. In the United States it has been used primarily for taste and odor control. The limited use in the United States has been due to its high costs, lack of residual, difficulty in storing and maintenance requirements.

Although ozone is effective in disinfecting water, its use is limited by its solubility. The temperature and pressure of water being treated regulate the amount of ozone that can be dissolved in the water. These factors tend to limit the disinfectant strength that can be made available to treat the water.

Many scientists claim that ozone destroys all microorganisms. Unfortunately, significant residual ozone does not guarantee that a water is safe to drink. Organic solids may protect organisms from the disinfecting action of ozone and increase the amount of ozone needed for disinfection.

In addition, ozone residuals cannot be maintained in metallic conduits for any period of time because of ozone's reactive nature. The inability of ozone to provide a residual in the distribution system is a major drawback to its use. However, recent information about the formation of trihalomethanes by chlorine compounds has resulted in renewed interest in ozone as an alternative means of disinfection.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.2A List the physical agents that have been used for disinfection other than chlorine.

6.2B List the chemical agents that have been used for disinfection other than chlorine.

6.2C What is a major limitation to the use of ozone?

6.22 Chlorine (Cl_2)

6.220 Properties of Chlorine

Chlorine is a greenish-yellow gas with a penetrating and distinctive odor. The gas is two-and-a-half times heavier than air. Chlorine has a very high coefficient of expansion. If there is a temperature increase of 50°F (28°C) (from 35°F to 85°F or 2°C to 30°C), the volume will increase from 84 to 89 percent. This expansion could easily rupture a cylinder or line full of liquid chlorine. For this reason all chlorine containers must not be filled to more than 85 percent of their volume. One liter of liquid chlorine can evaporate and produce 450 liters of chlorine gas.

Chlorine by itself is non-flammable and non-explosive, but it will support combustion. When the temperature rises, so does the vapor pressure of chlorine. This means that when the temperature increases, the pressure of the chlorine gas inside a chlorine container will increase. This property of chlorine must be considered when:

1. Feeding chlorine gas from a container, and
2. Dealing with a leaking chlorine cylinder.

6.221 Chlorine Disinfection Action

The exact mechanism of chlorine disinfection action is not fully known. One theory holds that chlorine exerts a direct action against the bacterial cell, thus destroying it. Another theory is that the toxic character of chlorine inactivates the *ENZYMES*[6] which enable living microorganisms to use their food supply. As a result, the organisms die of starvation. From the point of view of water treatment, the exact mechanism of chlorine disinfection is less important than its demonstrated effects as a disinfectant.

When chlorine is added to water, several chemical reactions take place. Some involve the molecules of the water itself, and some involve organic and inorganic substances suspended in the water. We will discuss these chemical reactions in more detail in the next few sections of this chapter. First, however, there are some terms associated with chlorine disinfection that you should understand.

When chlorine is added to water containing organic and inorganic materials, it will combine with these materials and form chlorine compounds. If you continue to add chlorine, you will eventually reach a point where the reaction with organic and inorganic materials stops. At this point, you have satisfied what is known as the *"CHLORINE DEMAND."*

The chemical reactions between chlorine and these organic and inorganic substances produce chlorine compounds. Some of these compounds have disinfecting properties; others do not. In a similar fashion, chlorine reacts with the water itself and produces some substances with disinfecting properties. The total of all the compounds with disinfecting properties *PLUS* any remaining free (uncombined) chlorine is known as the *"CHLORINE RESIDUAL."* The presence of this measurable chlorine residual is what indicates to the operator that all possible chemical reactions have taken place and that there is still sufficient *"AVAILABLE RESIDUAL CHLORINE"* to kill the microorganisms present in the water supply.

Now, if you add together the amount of chlorine needed to satisfy the chlorine demand and the amount of chlorine residual needed for disinfection, you will have the *"CHLORINE DOSE."* This is the amount of chlorine you will have to add to the water to disinfect it.

$$\text{Chlorine Dose, } mg/L = \text{Chlorine Demand, } mg/L + \text{Chlorine Residual, } mg/L$$

where

$$\text{Chlorine Residual, } mg/L = \text{Combined Chlorine Forms, } mg/L + \text{Free Chlorine, } mg/L$$

6.222 Reaction with Water (Hydrolysis[7])

Free chlorine combines with water to form hypochlorous and hydrochloric acids:

$$\text{Chlorine} + \text{Water} \rightleftharpoons \text{Hypochlorous Acid} + \text{Hydrochloric Acid}$$

$$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$$

---

[6] *Enzymes (En-zimes). Organic substances (produced by living organisms) which cause or speed up chemical reactions. Organic catalysts and/or biochemical catalysts.*

[7] *Hydrolysis (hi-DROLL-uh-sis). A chemical reaction in which a compound is converted into another compound by taking up water.*

Depending on the pH, hypochlorous acid may be present in the water as the hydrogen ion and hypochlorite ion (Figure 9.1).

Hypochlorous Acid ⇌ Hydrogen Ion + Hypochlorite Ion

$$HOCl \rightleftharpoons H^+ + OCl^-$$

In solutions that are dilute (low concentration of chlorine) and have a pH above 4, the formation of HOCl (hypochlorous acid) is most complete and leaves little free chlorine (Cl_2) existing. The hypochlorous acid is a weak acid and hence is poorly dissociated (broken up into ions) at pH levels below 6. Thus any free chlorine or hypochlorite (OCl^-) added to water will immediately form either HOCl or OCl^-, the species formed is thereby controlled by the pH value of the water. This is extremely important since HOCl and OCl^- differ in disinfection ability. HOCl has a much greater disinfection potential than OCl^-. Normally in water with a pH of 7.3, 50 percent of the chlorine present will be in the form of HOCl and 50 percent in the form of OCl^-. The higher the pH level, the greater the percent of OCl^-.

6.223 Reaction with Impurities in Water

Most waters that have been processed still contain some impurities. In this section we will discuss some of the more common impurities that react with chlorine and we will examine the effects of these reactions on the disinfection ability of chlorine.

A. Hydrogen sulfide (H_2S) and ammonia (NH_3) are two inorganic substances that may be found in water when it reaches the disinfection stage of treatment. Their presence can complicate the use of chlorine for disinfection purposes. This is because hydrogen sulfide and ammonia are what is known as *REDUCING AGENTS*. That is, they give up electrons easily. Chlorine reacts rapidly with these particular reducing agents producing some undesirable results.

Hydrogen sulfide produces an odor which smells like rotten eggs. It reacts with chlorine to form sulfuric acid and elemental sulfur (depending on temperature, pH and hydrogen sulfide concentration). Elemental sulfur is objectionable because it can cause odor problems and will precipitate as finely divided white particles which are sometimes colloidal in nature.

The chemical reactions between hydrogen sulfide and chlorine are as follows:

Hydrogen Sulfide + Chlorine + Oxygen Ion → Elemental Sulfur + Water + Chloride Ions

$$H_2S + Cl_2 + O^{2-} \rightarrow S\downarrow + H_2O + 2\,Cl^-$$

The chlorine required to oxidize hydrogen sulfide to sulfur and water is 2.08 mg/*L* chlorine to 1 mg/*L* hydrogen sulfide. The complete oxidation of hydrogen sulfide to the sulfate form is as follows:

Hydrogen Sulfide + Chlorine + Water → Sulfuric Acid + Hydrochloric Acid

$$H_2S + Cl_2 + 4\,H_2O \rightarrow H_2SO_4 + HCl$$

Thus, 8.32 mg/*L* of chlorine are required to oxidize one mg/*L* of hydrogen sulfide to the sulfate form. Note that in both reactions the chlorine is converted to the chloride ion (Cl^- or HCl) which has no disinfecting power nor produces any chlorine residual. In waterworks practice we always chlorinate to produce a chlorine residual, therefore the second reaction (complete oxidation of hydrogen sulfide) occurs before we have any chlorine residual in the water we are treating.

When chlorine is added to water containing ammonia (NH_3), it reacts rapidly with the ammonia and forms *CHLORAMINES*[8]. This means that less chlorine is available to act as a disinfectant. As the concentration of ammonia increases, the disinfectant power of the chlorine drops off at a rapid rate.

B. When organic materials are present in water being disinfected with chlorine, the chemical reactions that take place may produce suspected carcinogenic compounds (trihalomethanes). The formation of these compounds can be prevented by limiting the amount of prechlorination and by removing the organic materials prior to chlorination of the water.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.2D List two inorganic reducing chemicals that react rapidly with chlorine.

6.2E How is the chlorine demand determined?

6.2F How is the chlorine dosage determined?

6.23 Hypochlorite (OCl^-)

6.230 Reactions with Water

The use of hypochlorite to treat potable water achieves the same result as chlorine gas. Hypochlorite may be applied in the form of calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite (NaOCl). The form of calcium hypochlorite most frequently used to disinfect water is known as High Test Hypochlorite (*HTH*). The chemical reactions of hypochlorite in water are similar to those of chlorine gas.

CALCIUM HYPOCHLORITE

Calcium Hypochlorite + Water → Hypochlorous Acid + Calcium Hydroxide

$$Ca(OCl)_2 + 2\,H_2O \rightarrow 2\,HOCl + Ca(OH)_2$$

SODIUM HYPOCHLORITE

Sodium Hypochlorite + Water → Hypochlorous Acid + Sodium Hydroxide

$$NaOCl + H_2O \rightarrow HOCl + Na(OH)$$

Calcium hypochlorite (HTH) is used by a number of small water supply systems. A problem occurs in these systems when sodium fluoride is injected at the same point as the hypochlorite. A severe crust is formed when the calcium and fluoride ions combine.

6.231 Differences Between Chlorine Gas and Hypochlorite Compound Reactions

The only difference between the reactions of the hypochlorite compounds and chlorine gas is the "side" reactions of the end products. The reaction of chlorine gas tends to

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[8] *Chloramines (KLOR-uh-means). Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.*

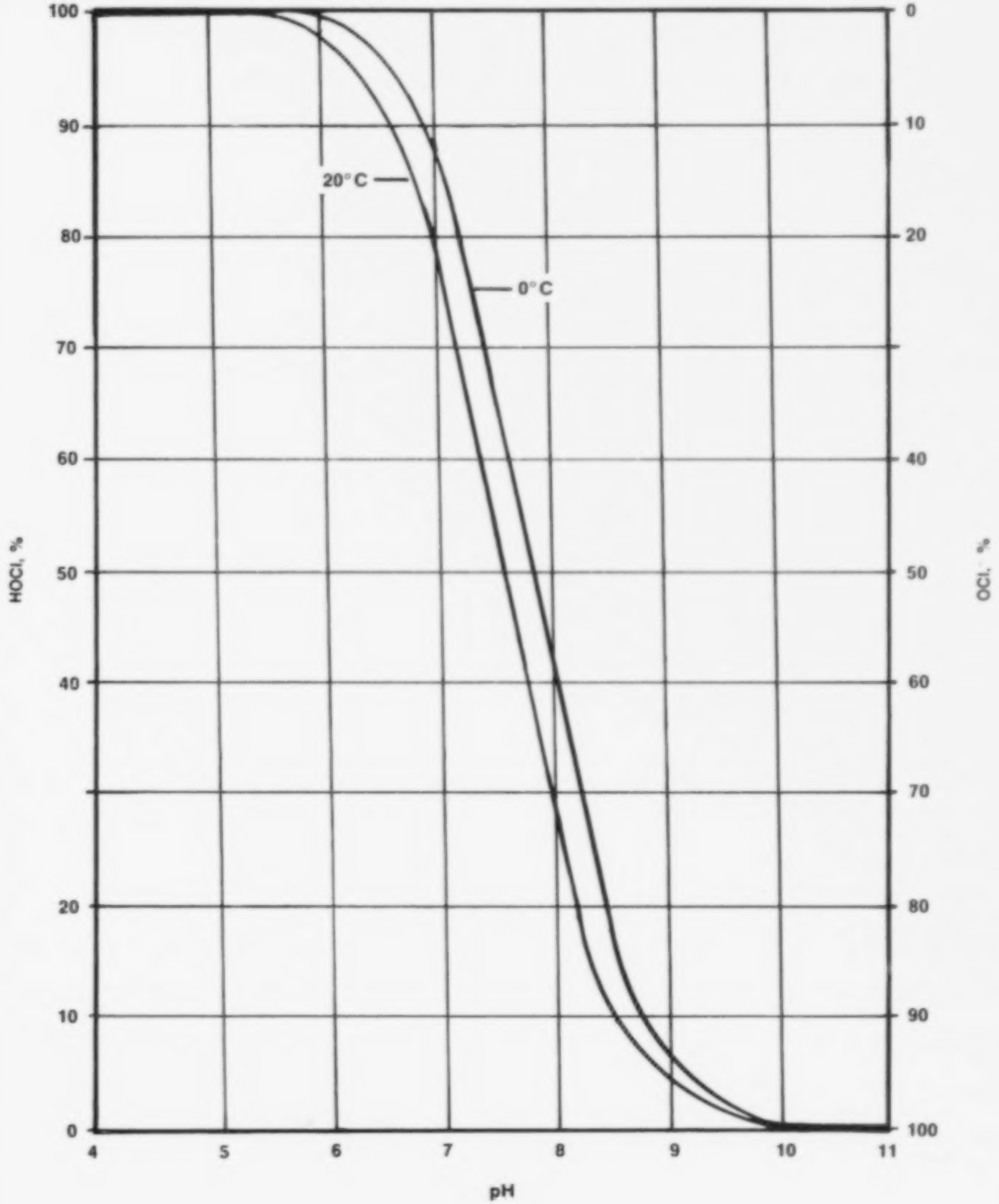

Fig. 6.1 Relationship between hypochlorous acid (HOCl), hypochlorite ion (OCl^-) and pH

lower the pH (increases the hydrogen ion (H^+) concentration) by the formation of hydrochloric acid which favors the formation of hypochlorous acid (HOCl). The hypochlorite tends to raise the pH with the formation of hydroxyl ions (OH^-) from the calcium or sodium hydroxide. At a high pH of around 8.5 or higher, the hypochlorous acid (HOCl) is almost completely dissociated to the ineffective hypochlorite ion (OCL^-) (Figure 6.1). This reaction also depends on the *BUFFER CAPACITY*[9] (amount of bicarbonate, HCO_3, present) of the water.

$$\underset{\text{Acid}}{\text{Hypochlorous}} \rightleftarrows \underset{\text{Ion}}{\text{Hydrogen}} + \underset{\text{Ion}}{\text{Hypochlorite}}$$

$$HOCl \rightleftarrows H^+ + OCl^-$$

6.24 Chlorine Dioxide (ClO_2)

6.240 Reaction in Water

Chlorine dioxide may be used as a disinfectant. Chlorine dioxide does not form carcinogenic compounds that may be formed by other chlorine compounds. Also it is not affected by ammonia, and is a very effective disinfectant at higher pH levels. In addition, chlorine dioxide reacts with sulfide compounds, thus helping to remove them and eliminate their characteristic odors. Phenolic tastes and odors can be controlled by using chlorine dioxide.

Chlorine dioxide reacts with water to form chlorate and chlorite ions in the following manner:

$$\underset{\text{Dioxide}}{\text{Chlorine}} + \text{Water} \rightarrow \underset{\text{Ion}}{\text{Chlorate}} + \underset{\text{Ion}}{\text{Chlorite}} + \underset{\text{Ions}}{\text{Hydrogen}}$$

$$2\,ClO_2 + H_2O \rightarrow ClO_3^- + ClO_2^- + 2\,H^+$$

6.241 Reactions with Impurities in Water

A. *INORGANIC COMPOUNDS*
Chlorine dioxide is an effective *OXIDIZING AGENT*[10] with iron and manganese and does not leave objectionable tastes or odors in the finished water. Because of its oxidizing ability, chlorine dioxide usage must be monitored and the dosage will have to be increased when treating waters with iron and manganese.

B. *ORGANIC COMPOUNDS*
Chlorine dioxide does not react with organics in water. Therefore, there is little danger of the formation of potentially dangerous trihalomethanes.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.2G How does pH influence the relationship between HOCl and OCl^-?

6.2H How does chlorine gas and hypochlorite influence pH?

6.25 Breakpoint Chlorination[11]

In determining how much chlorine you will need for disinfection, remember you will be attempting to produce a certain chlorine residual in the form of *FREE AVAILABLE RESIDUAL CHLORINE*[12]. Chlorine in this form has the highest disinfecting ability. *BREAKPOINT CHLORINATION* is the name of this process of adding chlorine to water until the chlorine demand has been satisfied. Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint. Public water supplies are normally chlorinated *PAST THE BREAKPOINT*.

Take a moment here to look at the breakpoint chlorination curve in Figure 6.2. Assume the water being chlorinated contains some manganese, iron, nitrate, organic matter and ammonia. Now add a small amount of chlorine. The chlorine reacts with (oxidizes) the manganese, iron and nitrite. That's all that happens — no disinfection and no chlorine residual (Figure 6.2, points 1 to 2). Add a little more chlorine, enough to react with the organics and ammonia; *CHLORORGANICS*[13] and *CHLORAMINES*[14] will form. The chloramines produce a combined chlorine residual — a chlorine residual combined with other substances so it has lost some of its disinfecting strength. Combined residuals have rather poor disinfecting power and may cause tastes and odors (points 1 to 3).

With just a little more chlorine the chloramines and some of the chlororganics are destroyed (points 3 to 4). Adding just one last amount of chlorine we get *FREE AVAILABLE RESIDUAL CHLORINE* (beyond point 4) — free in the sense that it has not reacted with anything and available in that it *CAN* and *WILL* react if need be. Free available residual chlorine is the best residual for disinfection. It disinfects faster and without the "swimming pool" odor of combined residual chlorine. Free available residual chlorine begins to form at the breakpoint; the process is called *BREAKPOINT CHLORINATION*. In water treatment plants today it is common practice to go "past the breakpoint." This means that the treated water will have a low chlorine residual, but the residual will be a very effective disinfectant because it is in the form of *FREE AVAILABLE RESIDUAL CHLORINE*.

Let's look more closely at some of the chemical reactions that take place during chlorination. When chlorine is added to waters containing ammonia (NH_3), the ammonia reacts with hypochlorous acid (HOCl) to form monochloramine, dichloramine and trichloramine. The formation of these chloramines depends on the pH of the solution and the initial chlorine-ammonia ratio.

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[9] *Buffer Capacity. A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water for offering a resistance to changes in pH.*

[10] *Oxidizing Agent. Any substance, such as oxygen (O_2) and chlorine (Cl_2), that will readily add (take on) electrons. The opposite is a reducing agent.*

[11] *Breakpoint Chlorination. The addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.*

[12] *Free Available Residual Chlorine. That portion of the total available residual chlorine composed of dissolved chlorine gas (Cl_2), hypochlorous acid (HOCl), and/or hypochlorite ion (OCl^-) remaining in water after chlorination. This does not include chlorine that has combined with ammonia, nitrogen, or other compounds.*

[13] *Chlororganic (chlor-or-GAN-nick). Organic compounds combined with chlorine. These compounds generally originate from, or are associated with, life processes such as those of algae in water.*

[14] *Chloramines (KLOR-uh-means). Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.*

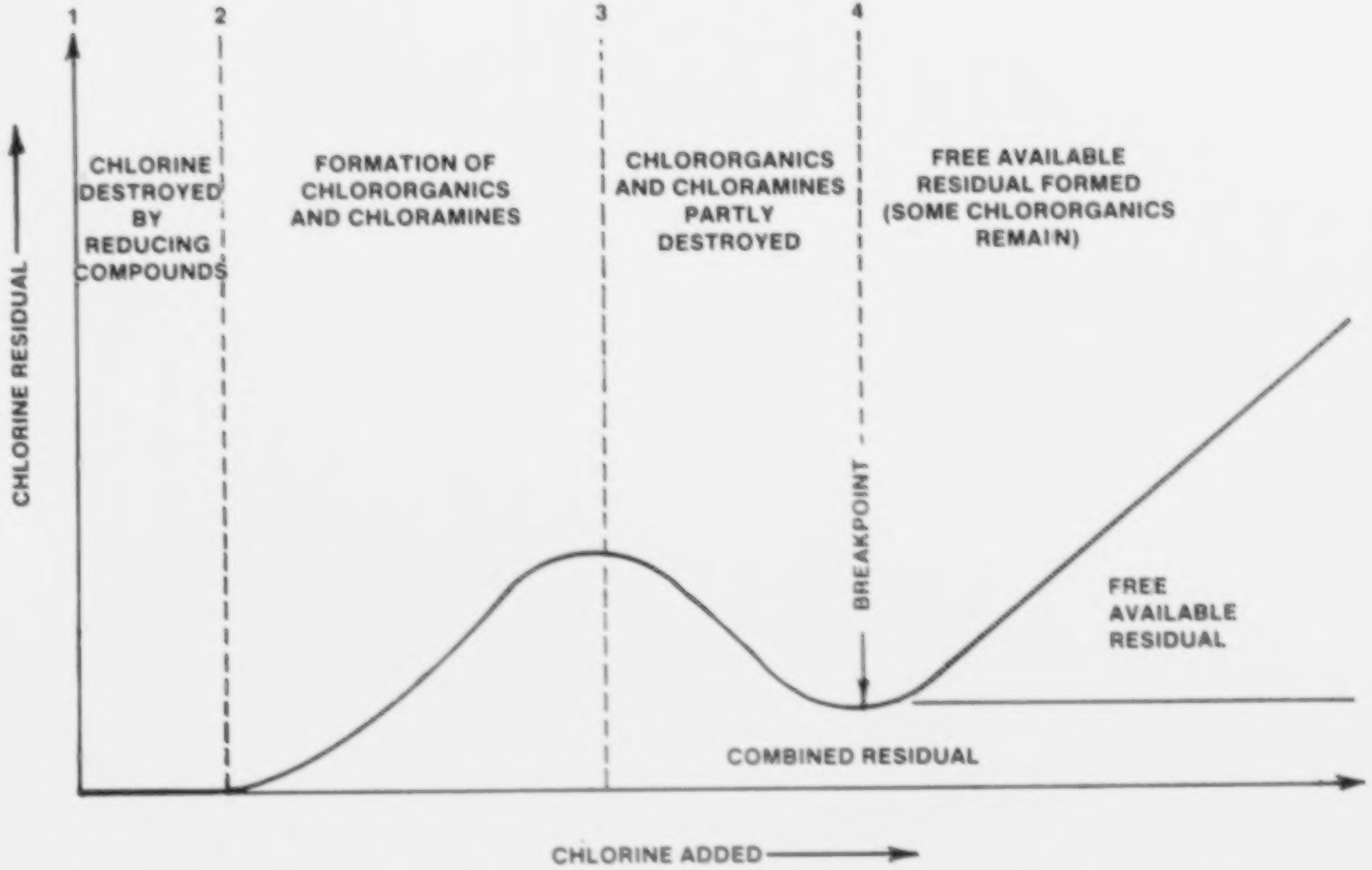

Fig. 6.2 Breakpoint chlorination curve

Ammonia + Hypochlorous Acid → Chloramine + Water

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ Monochloramine

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ Dichloramine

$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$ Trichloramine[15]

At the pH levels that are usually found in water (pH 6.5 to 9.5), monochloramine and dichloramine exist together. At pH levels below 5.5, dichloramine exists by itself. Below pH 4.0, trichloramine is the only compound found. The mono- and dichloramine forms have definite disinfection powers and are of interest in the measurement of chlorine residuals. Dichloramine has a more effective disinfecting power than monochloramine. However, dichloramine is not recommended as a disinfectant because of taste and odor problems. Chlorine reacts with *PHENOL*[16] and salicylic acid (both are leached into water from leaves and blossoms) to form *CHLOROPHENOL*[17] which has an intense medicinal odor. This reaction goes much slower in the presence of monochloramine.

Historically some plants add ammonia (aqua ammonia) to the filter effluent when they chlorinated (postchlorination) to produce chloramines. The reason for this practice was that chloramines produced very long lasting chlorine residuals. Today plants are considering adding ammonia because chloramines do not form trihalomethanes. A major limitation of using chloramine residuals is the fact that chloramines are not as effective as a disinfectant as free chlorine residuals. Another potential problem is that chloramines may cause tastes and odors in the treated water. Studies have indicated a dosage of three parts chlorine to one part ammonia (3:1) will form monochloramines. Monochloramines form combined residual chlorine (rising part of breakpoint curve in Figure 6.2) and apparently do not produce tastes and odors. Trichloramines form during the oxidation of combined residual materials (Figure 6.2) and will cause tastes and odors Trichloramines are formed past the breakpoint and also may form tastes and odors. Although chloramines are non-toxic to healthy humans, they can have a debilitating (weakening) effect on individuals with renal disease and who must undergo kidney dialysis.

In plants where triahalomethanes (THMs) are not a problem, sufficient chlorine is added to the raw water (prechlorination) to go "past the breakpoint." The chlorine residual will aid coagulation, control algae problems in basins, reduce odor problems in treated water, and provide sufficient chlorine contact time for an effective kill of pathogenic organisms. Therefore the treated water will have a very low chlorine residual, but the residual will be a very effective disinfectant.

6.26 Critical Factors

Both *CHLORINE RESIDUAL* and *CONTACT TIME* are essential for effective killing of pathogenic microorganisms. Complete initial mixing is very important. Changes in pH affect the disinfection ability of chlorine and you must reexamine the best combination of contact time and chlorine residual when the pH fluctuates. Critical factors influencing disinfection are summarized as follows:

1. Injection point and method of mixing to get disinfectant in contact with water being disinfected. Depends on whether using prechlorination or postchlorination.
2. Contact time. With good initial mixing, the longer the contact time, the better the disinfection.
3. Effectiveness of upstream treatment processes. The lower the turbidity (suspended solids, organic content, reducing agents) of the water, the better the disinfection.
4. Temperature. The higher the temperature, the more rapid the rate of disinfection.
5. Dosage and type of chemical. Usually the higher the dosage, the quicker the disinfection rate. The form (chloramines or free chlorine residual) and type of chemical also influences the disinfection rate.
6. pH. The lower the pH, the better the disinfection.

6.3 POINTS OF APPLICATION

6.30 Wells and Pumps[18]

6.300 Disinfecting New and Existing Wells

When a new well is completed, it is necessary to disinfect the well, pump and screen. A 50 mg/*L* residual of free chlorine in contact with all surfaces of the well, screen, pump and piping is recommended. Consideration must be given to the fact that the water aquifer could have been contaminated during the drilling process. Disinfection is usually accomplished by using a chlorine solution applied into the well and the aquifer around the well.

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[15] *More commonly called nitrogen trichloride.*

[16] ***Phenol (FEE-noll).*** *Organic compounds that are derivatives of benzene.*

[17] ***Chlorophenol (klor-o-FEE-noll).*** *Chlorophenolic compounds are phenolic compounds (carbolic acid) combined with chlorine.*

[18] ***Also see Section 3.5, "Disinfection of Wells and Pumps" in Chapter 3, SMALL WATER SYSTEM OPERATION AND MAINTENANCE.***

To accomplish this process the use of sodium hypochlorite is recommended. As previously mentioned, 50 mg/*L* is needed and 24 hours of contact time is recommended. At the end of this period, pump the well until all evidence of a chlorine residual is gone. Then take a sample and test for *TOTAL COLIFORMS*[19] to determine the effectiveness of the chlorine dosage.

Since organic matter such as oil may be used during drilling, the chlorine solution should have a concentration of about 1,000 mg/*L* before being injected into the well through the vent pipe. If the chlorine solution is applied to the well by injecting the chlorine through the pump column pipe, a chlorine dosage of 100 mg/*L* is acceptable. By using the column pipe, the oil on the water surface is avoided and the large amount of chlorine is not needed.

6.301 Sample Problem

FORMULAS

To disinfect a well, the first step is to determine the volume of water in the well. There are three approaches to calculating the volume of water in a well.

1. Calculate the volume of water using the diameter of the casing and the depth of water.

$$\text{Volume, gal} = \frac{(0.785)(\text{Diameter, in})^2(\text{Depth, ft})(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

2. When the depth of water in a well changes from time to time, many operators calculate a constant for their well in terms of gallons of water per foot of water in the well.

$$\text{Volume, gal/ft} = \frac{(0.785)(\text{Diameter, in})^2(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

3. Sometimes tables are available which allow you to find the volume in gallons per foot from the table if you know the diameter of the casing.

To find the pounds of chlorine needed to disinfect a well, we need to know the volume of water in gallons and the desired chlorine dose in milligrams per liter. Convert the volume in gallons to million gallons by dividing by 1,000,000.

$$\text{Volume, M Gal} = \frac{(\text{Volume, Gal})\ (1\ \text{Million})}{1{,}000{,}000}$$

$$\boxed{\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})}$$

We can "prove" the above formula if we know that one liter of water weighs 1,000,000 mg.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})\left(\frac{\text{Dose, mg}}{1{,}000{,}000\ \text{mg}}\right)(8.34\ \text{lbs/gal})$$

Note that the dose is now in milligrams per million milligrams, or parts per million. Now change the milligrams to pounds so we will have dose, pounds chlorine per million pounds of water.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})\left(\frac{\text{Dose, lbs}}{\text{M lbs}}\right)(8.34\ \text{lbs/gal})$$

To calculate the gallons of sodium hypochlorite needed to disinfect a well, we need to know the pounds of chlorine needed and the percent available chlorine in the hypochlorite.

$$\begin{matrix}\text{Sodium Hypochlorite}\\ \text{Solution, gallons}\end{matrix} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, }\%)}$$

EXAMPLE 1

A 200-foot deep new well is to be disinfected with a five percent sodium hypochlorite solution. The top 150 feet of the well has a 12-inch casing and the bottom 50 feet has an 8-inch casing and well screen. The water level in the well is at 80 feet from the top of the well. Since this is a new well, the desired chlorine concentration in the initial dose should be 100 mg/*L*. How many gallons of five percent sodium hypochlorite will be needed?

Known		Unknown
Depth of Well, ft	= 200 ft	5% Hypochlorite, gallons
Hypochlorite, %	= 5%	
Chlorine Dose, mg/*L*	= 100 mg/*L*	
Top 150 ft	= 12-in casing	
Bottom 50 ft	= 8-in casing and screen	
Water, level, ft	= 80 ft from top or = 120 ft from bottom	

1. Find the volume of water in the well. Use Table 6.4.

TABLE 6.4 VOLUME OF WATER IN WELL PER FOOT OF DEPTH

Casing Size, in	Volume, gallons per foot of depth
4	0.65
5	1.02
6	2.47
8	2.61
10	4.08
12	5.87
14	7.99
16	10.44
18	13.21
20	16.31

a. From 80 feet from top to 150 feet from top we have 70 feet (150-ft − 80 ft) of 12-inch casing.

From Table 6.4, 12-inch casing has 5.87 gallons of water per foot.

b. From 150 feet from top to 200 feet from top we have 50 feet (200 ft − 150 ft) of 8 in-inch casing.

From Table 6.4, 12-inch casing has 5.87 gallons of water per foot.

$$\begin{aligned}\begin{matrix}\text{Total Volume of}\\ \text{Water, gallons}\end{matrix} &= (\text{Length, ft})(\text{Volume, gal/ft})\\ &= (70\ \text{ft})(5.87\ \text{gal/ft}) + (50\ \text{ft})(2.61\ \text{gal/ft})\\ &= 411\ \text{gal} + 131\ \text{gal}\\ &= 542\ \text{gallons of water}\end{aligned}$$

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[19] *Total Coliforms. See procedures for Coliform in Chapter 7, "Laboratory Procedures," SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

If Table 6.4 was not available, we could calculate the approximate volume in gallons per foot of depth and the total volume of water in gallons.

a. For the 12-inch casing, calculate the volume in gallons per foot of depth.

$$\text{Volume, gal} = (\text{Area, sq ft})(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$= (\text{Area, sq ft})(7.48\ \text{gal/cu ft})(\text{Depth, ft})$$

$$\text{Volume, gal/ft} = (\text{Area, sq ft})(7.48\ \text{gal/cu ft})$$

$$= \frac{(0.785)(12\ \text{in})^2(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

$$= 5.87\ \text{gal/ft}$$

b. For the 8-inch casing, calculate the volume in gallons per foot of depth.

$$\text{Volume, gal/ft} = (\text{Area, sq ft})(7.48\ \text{gal/cu ft})$$

$$= \frac{(0.785)(8\ \text{in})^2(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

$$= 2.61\ \text{gal/ft}$$

$$\begin{array}{c}\text{Total Volume of}\\ \text{Water, gallons}\end{array} = (\text{Length, ft})(\text{Volume, gal/ft})$$

$$= (70\ \text{ft})(5.87\ \text{gal/ft}) + (50\ \text{ft})(2.61\ \text{gal/ft})$$

$$= 411\ \text{gal} + 131\ \text{gal}$$

$$= 542\ \text{gallons of water}$$

This answer is the same as the 542 gallons we obtained using the values in Table 6.4

2. Find the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Vol Water, M Gal})(\text{Chlorine Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.000542\ \text{M Gal})(100\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 0.45\ \text{lbs chlorine}$$

3. Calculate the gallons of 5 percent sodium hypochlorite solution needed.

$$\begin{array}{c}\text{Sodium Hypochlorite}\\ \text{Solution, gallons}\end{array} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(0.45\ \text{lbs})(100\%)}{(8.34\ \text{lbs/gal})(5\%)}$$

$$= 1.08\ \text{gallons}$$

A little over one gallon of 5 percent solution sodium hypochlorite should do the job.

The gravel in a gravel envelope well must be disinfected as the gravel is added to the well. This is accomplished by adding half a pound (227 gm) of five gram *HTH*[20] granules per ton of gravel.

When disinfecting a well that draws from more than one aquifer, remember that there is nearly always flow from one aquifer to another. Also if water is flowing through a well, the procedures described in this chapter may not work very well because the flowing water will carry away the chlorine.

Once water from a well starts producing positive coliform test results, it is almost impossible to correct the problem with chlorine treatment. However, some wells will clear up after long periods of pumping (sometimes two years are required).

Disinfection of the well may not be accomplished the first time so this procedure may have to be repeated a second and even possibly a third time.

PROCEDURES

6.302 Procedures

Procedures described in this section are one method for disinfecting a well; however, other methods are available and may be used.

a. Calculate volume of water in well using guidelines in Example 1.

b. Wash the pump column or drop pipe (pipe attached to the pump) with chlorine solution as it is lowered into well. The chlorine solution can be fed through a hose to wash the pipe.

c. After the chlorine solution has been fed into the well, operate the pump so as to thoroughly mix the disinfectant with the water in the well. Pump until the water discharged has the odor of chlorine. Then shutdown pump and let water surge back down into well. Repeat this procedure several times over an hour.

d. Allow the well to stand for 24 hours.

e. Pump well to waste until all traces of chlorine are gone.

f. Take a bacteriological sample for analysis. Use the 24-hour membrane filter method for the quickest results.

g. If results of bacteriological analysis for total coliforms indicate unsafe conditions, repeat disinfection procedure. Conditions are considered unsafe when the test results are positive (there are coliforms present).

6.303 Continuous Disinfecting of Wells

Normally wells are treated by a single application of disinfecting solution, but since more and more groundwater sources are becoming contaminated, it is becoming a standard practice to disinfect groundwaters on a continuous basis.

The type of disinfection installation to be used will depend on which type of chemicals are to be used. From a safety standpoint the use of hypochlorite is the safest. Normally there are fewer hazards associated with hypochlorite compounds than with liquid or gaseous chlorine. However, liquid or gaseous chlorine is cheaper to use than hypochlorite, especially if large volumes of chlorine are required.

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[20] *HTH. High Test Hypochlorite. Calcium hypochlorite or Ca(OCl$_2$).*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.3A When disinfecting a well, why should the well, pump, screen and aquifer around the well all be disinfected?

6.3B Where should the chlorine be applied to a well being disinfected?

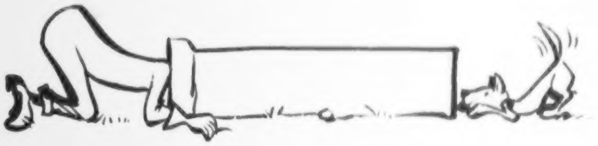
6.3C How would you determine if a well has been successfully disinfected?

6.31 Mains

6.310 Procedures

A. Preventive Measures

One of the most effective steps in disinfecting water mains is to do everything possible to prevent the mains from becoming contaminated. Keep as much outside material such as dirt, construction materials, animals, rodents and dirty water out of mains being installed or repaired. Inspect the interior of all pipes for cleanliness as the main is laid in the trench. Keep the trenches dry or dewatered. Install watertight plugs in all open-end joints whenever the trench is unattended for any length of time. An exception to the use of watertight plugs in the open ends of joints is when groundwater could cause the pipe to float. When a long pipeline is to be laid, a dry trench may not always be possible during the night when crews are not on duty.



B. Preliminary Measures

Flush the mains before attempting to disinfect them. Flushing is not an alternative to cleanliness when laying or repairing mains. Flushing cannot be expected to remove debris caked on joints, crevices and other parts of the system. Flush the mains using water flowing with a velocity of at least 2.5 ft/sec (0.75 m/sec). See Table 6.5 for flows required in gallons per minutes (GPM) to flush various diameter mains with 2.5 ft/sec and 5.0 ft/sec flushing velocities.

Special care must be exercised to be sure fittings and valves are clean before disinfecting a main. Also, all air pockets or other conditions which would prevent proper disinfection should be eliminated. Many water mains contain mechanical joints. These joints have spaces that are difficult to chlorinate once they become filled with water. This is one reason why initial flushing may be ineffective. Some operators crush calcium hypochlorite tablets and place the crushed tablets in joints to improve the disinfection process.

TABLE 6.5 FLOWS REQUIRED FOR VARIOUS FLUSHING VELOCITIES

Line Size, Inches	Flow Required, GPM[a] Velocity, 2.5 ft/sec	Velocity, 5 ft/sec
4	100	200
6	220	440
8	390	780
10	610	1,220
12	880	1,760
14	1,200	2,400
16	1,570	3,140

[a] Line should be flushed for at least 30 minutes.

If you wish to calculate the flow required in gallons per minute of any pipe diameter and flushing velocity not shown in Table 6.5, or if you wish to verify any number in Table 6.5, use the following procedure.

1. Calculate the cross-sectional area of the pipe in square feet. Use a 10-inch diameter pipe.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

$$= \frac{(0.785)(10 \text{ in})^2}{144 \text{ sq in/sq ft}}$$

$$= 0.545 \text{ sq ft}$$

2. Calculate the flow rate in cubic feet per second (CFS). Use a velocity of five feet per second and $Q = AV$.

$$\text{Flow Rate, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= (0.545 \text{ sq ft})(5 \text{ ft/sec})$$

$$= 2.725 \text{ CFS}$$

3. Convert the flow from cubic feet per second to gallons per minute.

$$\text{Flow Rate, GPM} = (\text{Flow, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= (2.725 \text{ cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= 1{,}223 \text{ GPM}$$

NOTE: Table 9.5 shows a flow of 1220 GPM because this is as close as you can read most flow meters, as well as regulate the flow.

C. Disinfection Methods

Next a method of disinfection must be selected. Chlorine gas may be used. A trained operator is required to operate the solution-feed chlorinator in combination with a booster pump. Applying gas directly from a cylinder is dangerous and if proper mixing of chlorine and water is not obtained, a highly corrosive condition could develop.

Another danger is that water could be drawn back into the chlorine cylinder. A mixture of water and liquid chlorine will form a very concentrated hydrochloric acid solution. This acid solution could "eat" a hole in the wall of the cylinder and allow liquid or gaseous chlorine to escape. For these reasons, *NEVER* use water on a chlorine leak. The corrosive action of chlorine and water will *ALWAYS* make a leak worse.

Calcium hypochlorite is available in powder, granular or tablet form at 65 percent available chlorine. Calcium hypochlorite is relatively soluble in water and can be applied by the use of a solution feeder. When using calcium hypochlorite (chlorine) tablets, the tablets will not dissolve readily if the water temperature is below 41°F (5°C), which will reduce the chlorine concentration in the water being disinfected. Temperature control of water is difficult, but you can control contact time. Therefore, if you are disinfecting when the water temperature is low, increase the contact time to achieve effective disinfection.

Calcium hypochlorite requires special storage to avoid contact with organic material. When organic material and calcium hypochlorite come in contact, the resulting chemical reactions can generate enough heat and oxygen to start and support a fire. When calcium hypochlorite is mixed with water, heat is given off. To adequately disperse the heat generated, the dry calcium hypochlorite should be added to the correct volume of water, rather than adding water to the calcium hypochlorite.

Sodium hypochlorite is available in liquid form at five to fifteen percent available chlorine and can be fed by the use of a hypochlorinator. Sodium hypochlorite can lose from two to four percent of its available chlorine content per month at room temperatures. Therefore, manufacturers recommend a maximum storage period of from 60 to 90 days.

See Section 6.4, "Operation of Chlorination Equipment," for procedures on how to operate equipment.

Three common methods of disinfecting mains are summarized in Table 6.6, "Chlorination Methods for Disinfecting Water Mains," and two methods are illustrated in Figures 6.3 and 6.4.

TABLE 6.6 CHLORINATION METHODS FOR DISINFECTING WATER MAINS

Chlorination Method Used	Maximum Chlorine Dose, mg/*L*[b]	Minimum Contact Time, hr	Minimum Chlorine Residual, mg/*L*
Continuous	50	24	25
Slug	500	3	300
Tablet[a]	50	24	25

[a] Tablets must be placed at inside top of pipe when the pipe is being laid. Also, two tablets must be placed at all joints on both sides of the pipe at the half-full location. Place one ounce (28 gm) of HTH powder per inch (25 mm) of pipe diameter in the first length of pipe and again after each 500 feet (150 m) of pipe. This assures that the first water entering the spaces at joints will have a high chlorine residual. Fill the pipe with water at velocities of less than one ft/sec.

[b] *NOTE:* AWWA Standard C601-81 recommends the following doses: Continuous, 25 mg/*L*; Slug, 100 mg/*L*; and Tablet, 25 mg/*L*. Use whatever dose you need that will produce no positive coliform test results.

WARNING

Do not use HTH powder in pipes with solvent welded plastic or screwed joint steel pipe because reaction between the joint compounds and the calcium hypochlorite could cause a fire or an explosion.

1. *NEW MAINS*

All pipes, fittings, valves, and other items which will not be disinfected by the filled line must be precleaned and disinfected. Valve bonnets and other high spots where cleaning may not be effective due to air pockets should be precleaned and chlorinated. Calcium hypochlorite tablets may be crushed and placed in joints and hydrant branches to assist in the total disinfection process.

When applying chlorine by either the continuous or slug method, be sure that the chlorine fed is well mixed with the water used to fill the pipe. Solution feeders can be used to inject chlorine into the water (continuous or slug method) used to disinfect the main. If possible, recycle the flows from the continuous method to minimize the use of chlorine and any problems that might be encountered from disposal of water with a high chlorine residual.

Care must be exercised when disposing of all water with a high chlorine residual (greater than 1 mg/*L*). Possible means of disposal include sanitary sewers, storm sewers or on land. If sanitary sewers are used, there should be adequate dilution and travel time so there will be no chlorine residual when the water reaches the wastewater treatment plant. Be sure to notify the plant operator in advance. If a storm sewer is used, be sure there is no chlorine residual remaining when the water reaches the receiving waters (creek, river, or lake). Chlorine is toxic to fish and other aquatic life. Land disposal may be acceptable if percolation rates are high and there are no nearby wells pumping groundwater.

2. *MAIN REPAIRS*

a. If repairs are made with the line continuously full of water and under pressure, no disinfection is required.

b. Where lines are opened:

(1) Dewater open trench areas using trash pumps,
(2) Flush and swab all portions of all pipe, fittings, and materials used in repairs, and which will be in contact with the water supply, with a 5 percent hypochlorite solution,
(3) Flush system, and
(4) Disinfect the main. Slug disinfection is recommended if practical using 500 mg/*L* dosage and 30-minute minimum contact.

D. Flushing After Disinfection

Flush lines after disinfection under all alternative procedures until residual chlorine is less than 1 mg/*L*. Velocity of flushing is not critical if the preventive and preliminary procedures described above were adequately performed.

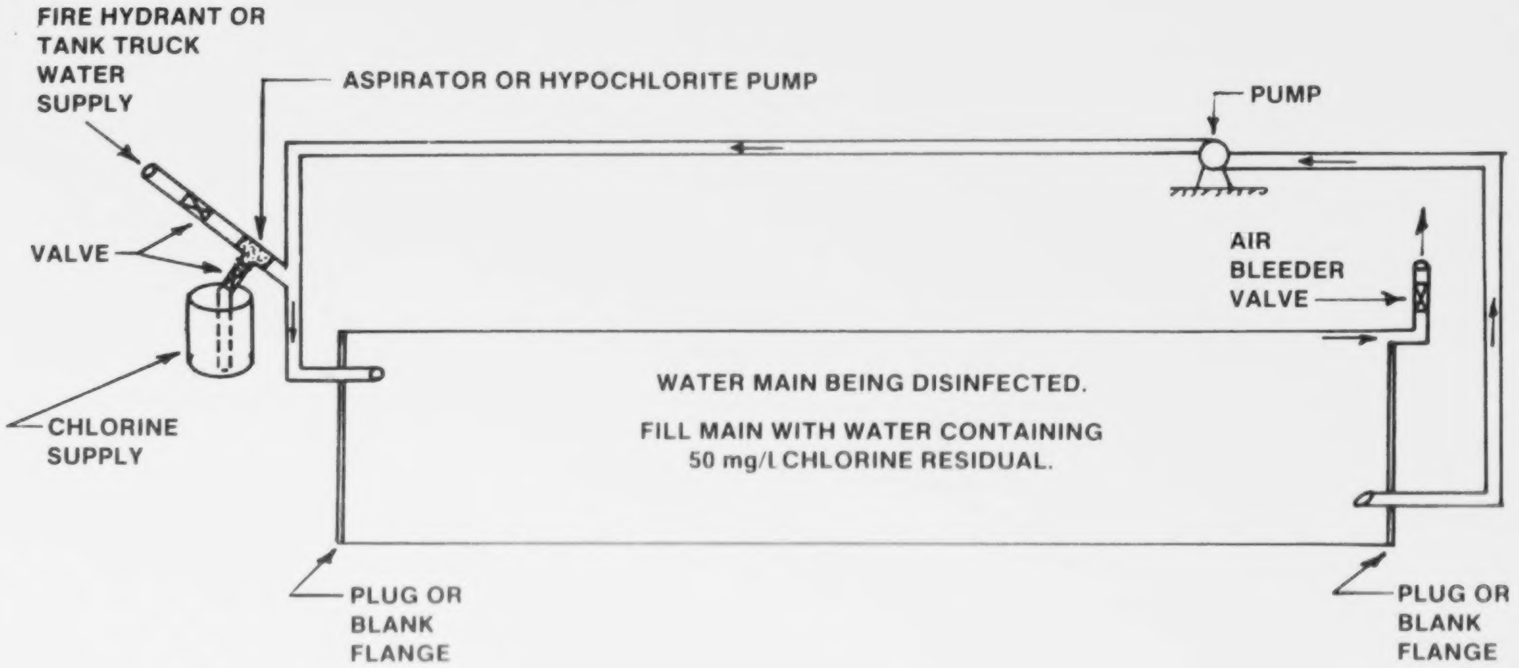
E. Testing After Disinfection

After disinfection and prior to placing line in service, bacteriological tests (24-hour membrane filter) are required as follows:

1. In a chlorinated water system, test at least one sample for each section disinfected.
2. Test at least two samples for each section disinfected if an unchlorinated water system.
3. For long lines, test samples along line. Line in excess of 2500 feet (750 meters) is considered a long line.

If bacteriological tests are unsatisfactory, disinfection must be repeated. Repeat of tablet method, of course, is impossible and an alternative procedure must be used.

A suggested procedure is to flush the main again and then take additional samples. Be sure the sample tap is satisfactory because many unsatisfactory samples from new mains are the result of using poor sample taps such as fire hydrants and blow-off valves.


FIRE HYDRANT OR
TANK TRUCK
WATER
SUPPLY
ASPIRATOR OR HYPOCHLORITE PUMP
PUMP
VALVE
AIR
BLEEDER
VALVE
CHLORINE
SUPPLY
WATER MAIN BEING DISINFECTED.
FILL MAIN WITH WATER CONTAINING
50 mg/l CHLORINE RESIDUAL.
PLUG OR
BLANK
FLANGE
PLUG OR
BLANK
FLANGE

CHLORINE SUPPLY

CAN USE HYPOCHLORITE AND PREMIX SOLUTION PRIER TO INJECTION.

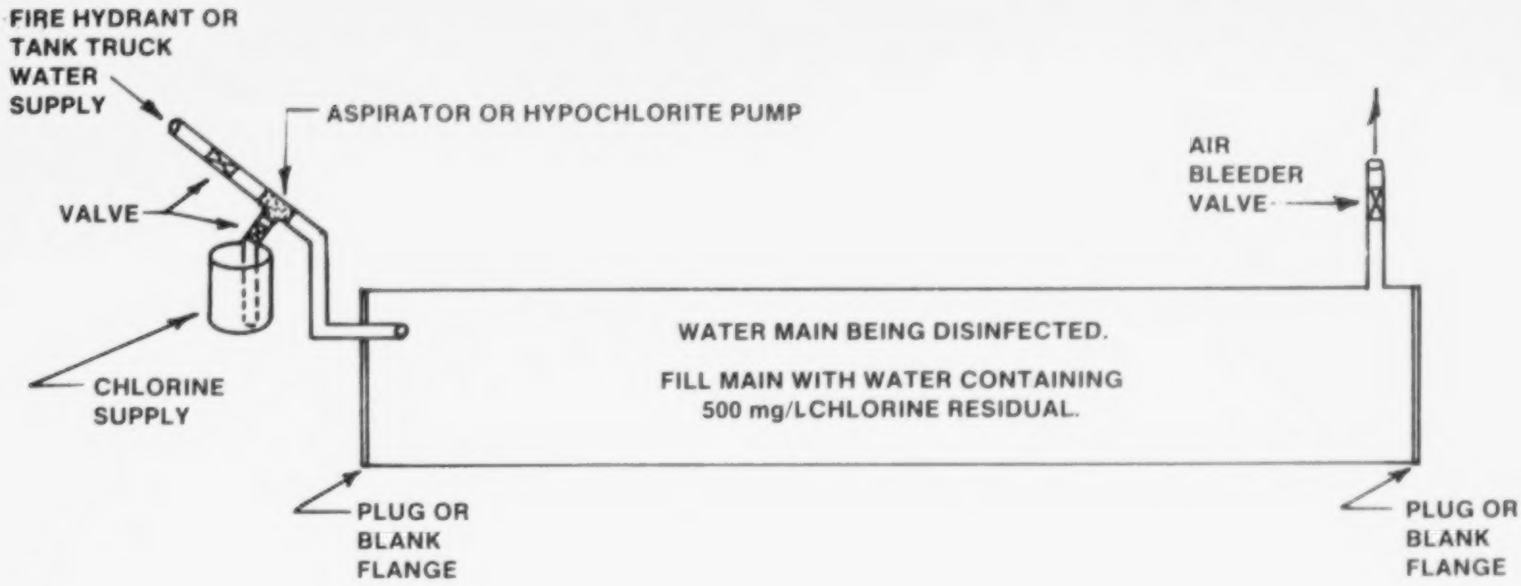
FILLING MAIN

WATER AND CHLORINE SOLUTION SHOULD BE ADDED UNTIL MAIN IS COMPLETELY FULL. ALLOW AIR TO ESCAPE THROUGH AIR BLEEDER VALVE.

EMPTYING MAIN

USE CAUTION WHEN DISPOSING OF DISINFECTING SOLUTION. IF DISCHARGING TO SEWER SYSTEM BE SURE THAT THE PLANT OPERATOR IS NOTIFIED. DISCHARGE WATER TO SEWER VERY SLOWLY OVER A PERIOD OF TIME RATHER THAN IN ONE LARGE SLUG.

Fig. 6.3 Disinfection of a water main by the continuous method


FIRE HYDRANT OR TANK TRUCK WATER SUPPLY
ASPIRATOR OR HYPOCHLORITE PUMP
VALVE
CHLORINE SUPPLY
AIR BLEEDER VALVE
WATER MAIN BEING DISINFECTED.
FILL MAIN WITH WATER CONTAINING 500 mg/LCHLORINE RESIDUAL.
PLUG OR BLANK FLANGE
PLUG OR BLANK FLANGE

CHLORINE SUPPLY

RECOMMEND USING HYPOCHLORITE. TABLETS CAN BE USED, BUT NOT AS EFFECTIVE.

FILLING MAIN

WATER AND CHLORINE SOLUTION SHOULD BE ADDED UNTIL WATER COMES OUT AIR BLEEDER VALVE.

EMPTYING MAIN

DISCHARGE DISINFECTING SOLUTION TO SEWER IF AVAILABLE. NOTIFY PLANT OPERATOR. IF SEWER NOT AVAILABLE, HAUL TO NEAREST WASTEWATER PLANT. DISCHARGE TO SEWER OR AT PLANT VERY SLOWLY AND DILUTE IF NECESSARY SO A SHOCK LOAD WILL NOT REACH PLANT.

Fig. 6.4 Disinfection of a water main by the slug method

If samples are still unsatisfactory, dewater the main as completely as possible. Use air compressors to blow out all remaining water. Refill the empty main with water containing a chlorine residual between 50 and 100 mg/*L*. Allow this water to stand in the main for 48 hours. Flush the main again and resample. Also collect samples from the water entering the main to be sure that this water is not the source of the positive coliform test results.

6.311 Emergency or Maintenance Disinfection

Mains may be disinfected by spraying a high concentration of chlorine on the insides of the mains. This method is often used for disinfecting sections of a water main where a break is repaired or where a crew has cut into an existing main, or in the very short (less than 100 feet or 30 meters) extension of an existing main. This method is frequently used when the main must be quickly returned to service and you can't wait for a 24-hour contact time.

Spray with a solution of one to five percent (10,000 to 50,000 mg/*L*) chlorine at a pressure of 100 psi (690 kPa or 7 kg/sq cm). An ordinary pressure type stainless steel fire extinguisher will do the job. Spray the complete interior of each section of pipe or fitting as it is lowered into the trench. The stainless steel extinguisher will not corrode as rapidly from contact with the chlorine solution if the interior of the tank is lined with a protective coating, such as a chlorinated rubber or an epoxy coating.

6.312 Disinfection Specifications

If water mains are to be disinfected by others as part of a contract, the following should be included in the specifications:

1. Specify AWWA C601-81 as the standard for disinfection procedures to be followed,
2. Specify where flushing may be done, rates of flushing, and location of suitable drainage facilities,
3. Form of chlorine to be used and method of application,
4. The type, number and frequency of samples for bacteriological tests,
5. The method of taking samples, and
6. Who is responsible for testing and use of a certified laboratory.

6.313 Areas of Disinfection Problems

When disinfecting mains, there are certain aspects which are most likely to cause problems. Joints and connections must be thoroughly cleaned before the mains are disinfected. Whenever anyone connects a service line into a main, they must use clean tools and materials. Each service line should be disinfected before being connected to a water main.

Some water supply systems may be lax with their disinfection practices. Personnel working for these systems are sometimes inadequately trained, under-paid and understaffed. They use the excuse that they have neither the time nor the budget to adequately disinfect new mains and existing mains after repairs.

THERE IS NO EXCUSE NOR REASON FOR EVER PLACING A LINE IN SERVICE THAT HAS NOT BEEN ADEQUATELY DISINFECTED AND CONFIRMED BY THE 24-HOUR MEMBRANE FILTER TEST FOR COLIFORMS.

6.314 Sample Problem

FORMULAS

Use the same formulas that are used to disinfect a well.

EXAMPLE 2

A new 6-inch water main 500 feet long needs to be disinfected. An initial chlorine dose of 400 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many gallons of 5 percent sodium hypochlorite solution will be needed?

Known	Unknown
Diameter of Pipe, in = 6 in	5% Hypochlorite, gallons
Length of Pipe, ft = 500 ft	
Chlorine Dose, mg/*L* = 400 mg/*L*	
Hypochlorite, % = 5%	

1. Calculate the volume of water in the pipe in gallons.

$$\text{Pipe Volume, gallons} = (0.785)(\text{Diameter, ft})^2(\text{Length, ft})(7.48\text{ gal/cu ft})$$

$$= \frac{(0.785)(6\text{ in})^2(500\text{ ft})(7.48\text{ gal/cu ft})}{144\text{ sq in/sq ft}}$$

$$= 735\text{ gallons of water}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.000735\text{ M Gal})(400\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 2.45\text{ lbs chlorine}$$

3. Calculate the gallons of 5 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(2.45\text{ lbs})(100\%)}{(8.34\text{ lbs/gal})(5\%)}$$

$$= 5.9\text{ gallons}$$

Six gallons of 5 percent solution sodium hypochlorite should do the job.

TANKS!
YOU'RE WELCOME!

6.32 Tanks

6.320 Procedures

Procedures for disinfecting tanks are similar to those used for mains. Thoroughly clean the tank after construction, maintenance or repairs. Add chlorine to the water used to fill the tank during the disinfection process and mix thoroughly. Maintain a chlorine residual of at least 50 mg/*L* for at least six hours and preferably for 24 hours. When the disinfection procedure is completed, carefully dispose of the disinfection water using the same procedures as for disposal of water used to disinfect mains.

When disinfecting large tanks which hold more than one million gallons, it may not be practical or economical to fill and drain the tank with a disinfecting solution with a high chlorine residual. A solution to this problem is to fill the tank, increase the chlorine residual slightly, collect samples, and run bacteriological tests while keeping the tank full of water **(see *SPECIAL NOTE, Section 6.34). If results from the 24-hour membrane filter tests are acceptable, the tank may be** placed in service. If necessary, dilute the tank contents as the water flows into the distribution system.

Another approach to disinfecting large tanks is to spray the walls with a jet of water containing a chlorine residual of 200 mg/*L*. Thoroughly spraying the walls with water with a high chlorine residual is an effective means of disinfecting large tanks. Operators doing the spraying should wear a self-contained breathing apparatus because the chlorine fumes from the spray water are very unpleasant and could be hazardous to your health. Be sure to provide plenty of ventilation.

6.321 Sample Problem

FORMULAS

Use the same formulas used to disinfect wells.

EXAMPLE 3

A new service storage reservoir needs to be disinfected before being placed in service. The tank is 8 feet high and 20 feet in diameter. An initial chlorine dose of 100 mg/*L* is expected to maintain a chlorine residual of over 50 mg/*L* during the 24-hour disinfection period. How many gallons of five percent sodium hypochlorite solution will be needed?

Known		**Unknown**
Diameter of Tank, ft	= 20 ft	5% Hypochlorite, gallons
Height of Tank, ft	= 8 ft	
Chlorine Dose, mg/*L*	= 100 mg/*L*	
Hypochlorite, %	= 5%	

1. Calculate the volume of water in the tank in gallons.

$$\text{Tank Volume, gallons} = (0.785)(\text{Diameter, ft})^2(\text{Heights, ft})(7.48\text{ gal/cu ft})$$

$$= (0.785)(20\text{ ft})^2(8\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 18{,}800\text{ gallons}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Vol Water, M Gal})(\text{Chlorine Dose, mg/}L)(8.34\text{ lbs/gal})$$

$$= (0.0188\text{ M Gal})(100\text{ mg/}L)(8.34\text{ lbs/gal})$$

$$= 15.68\text{ lbs chlorine}$$

3. Calculate the gallons of 5 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(15.68\text{ lbs})(100\%)}{(8.34\text{ lbs/gal})(5\%)}$$

$$= 37.6\text{ gallons}$$

Thirty-eight gallons of five percent sodium hypochlorite solution should do the job.

6.33 Water Treatment Plants

For additional information on disinfection at water treatment plants, see Chapter 4, "Small Water Treatment Plants," Section 4.5, "Disinfection" in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE*, and Chapter 7, "Disinfection," in *WATER TREATMENT PLANT OPERATION*, Volume I, in this series of manuals.

6.34 Sampling

**SPECIAL NOTE*

Whenever you collect a sample for a bacteriological test (coliforms), be sure to use a sterile plastic or glass bottle. If the sample contains any chlorine residual sufficient sodium thiosulfate should be added to neutralize all of the chlorine residual. Usually 0.1 m*L* of a 10 percent solution of sodium thiosulfate added to the 120 m*L* (4 oz) bottle before sterilization is sufficient, unless you are disinfecting mains or storage tanks. If the chlorine residual in the sample is greater than 15 mg/*L*, more "thio" is required to neutralize the chlorine.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.3D How can water mains be kept clean during construction or repair?

6.3E What areas in a water main require extra effort for successful disinfection?

6.3F List three forms of chlorine used for disinfection.

6.3G What precautions should be taken when disposing of water with a high chlorine residual?

6.3H Before a water main is disinfected, what flushing velocity should be used and for how long?

End of Lesson 1 of 2 Lessons
on
DISINFECTION

DISCUSSION AND REVIEW QUESTIONS

Chapter 6. DISINFECTION

(Lesson 1 or 2 Lessons)

Write the answers to these questions in your notebook before continuing.

1. Why is drinking water disinfected?
2. If a water is disinfected, will it be safe to drink?
3. What is the chlorine demand of a water?
4. How would you determine the chlorine dose for water?
5. Why should a chlorine residual be maintained in a water distribution system?
6. Why would you consider recycling water used to disinfect a water main when using the continuous chlorination method?
7. How would you dispose of the water used to disinfect a water main when using the slug chlorination method?

Chapter 6. DISINFECTION

(Lesson 2 of 2 Lessons)

6.4 OPERATION OF CHLORINATION EQUIPMENT

6.40 Description of Various Units

6.400 Field Equipment

1. *HYPOCHLORINATORS*

Hypochlorinators used on small water systems are very simple and relatively easy to install. Typical installations are shown in Figures 6.5 and 6.6. Hypochlorinator systems usually consist of a chemical solution tank for the hypochlorite, diaphragm-type pump (Figure 6.7), power supply, water pump, pressure switch and water storage tank.

There are two methods of feeding the hypochlorite solution into the water being disinfected. The hypochlorite solution may be pumped directly into the water (Figure 6.8). In the other method, the hypochlorite solution is pumped through the *EDUCTOR*[21] or injector which draws in additional water for dilution of the hypochlorite solution (Figure 6.9).

2. *CHLORINATORS*

Chlorinators on small systems are normally vacuum feed systems (Figures 6.10, 6.11 and 6.12). The chlorine is usually injected directly into the water pipe supply and there may not be contact chambers or mixing units. The location of the injection point is important. The injection should never be on the intake side of the pump as it will cause corrosion problems. There should be a check valve and a meter to monitor the chlorine dose.

On most well applications a chlorine booster pump is needed to overcome the higher water pump discharge pressures. The low volume-high pressure booster pump shown in Figure 6.10 must have extremely small clearance between the impeller and the casing. If the well produces sand in the water, this pump will wear rapidly and become unreliable. In this situation, the chlorine solution should be introduced down the well through a polyethylene tube.

The polyethylene tube (½ inch or 12 mm) must be installed in the well so as to discharge a few inches below the suction screen. The chlorinator should operate *ONLY* when the pump is running. The chlorine solution flowing through the polyethylene tube is extremely corrosive. If the tube does not discharge into flowing water, the effect of the solution impinging on metal surface can be disastrous. Wells have been destroyed by corrosion from chlorine.

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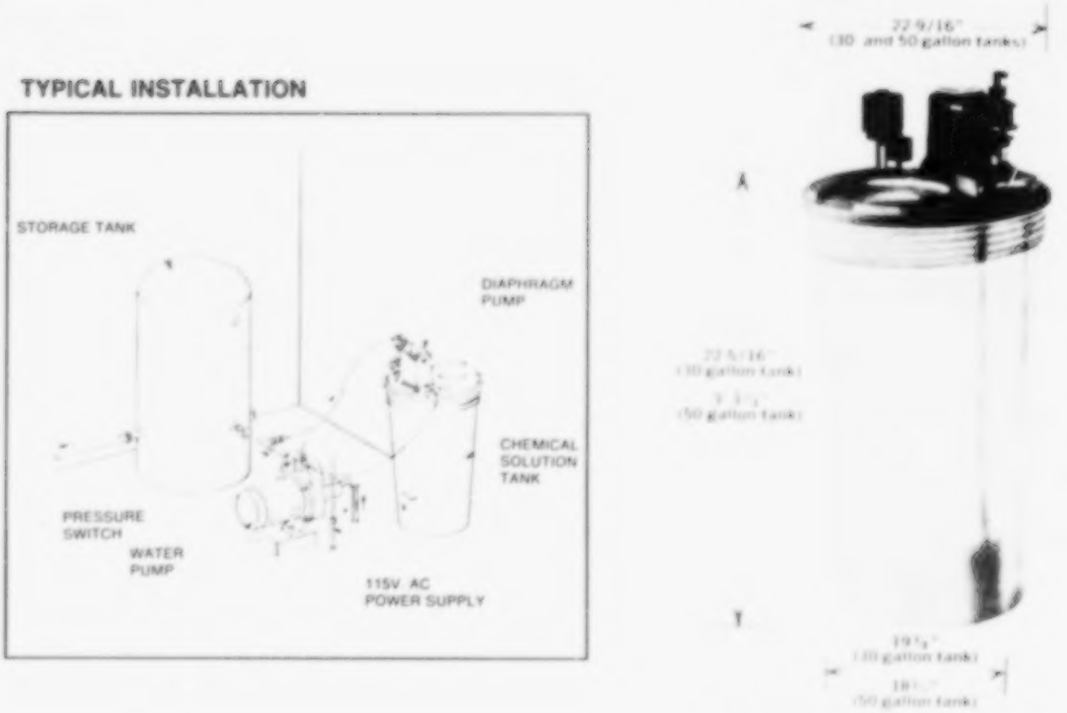
[21] *Eductor (e-DUCK-tor). A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction such as a Venturi.*



Pump tank system for chemical mixing and metering. Cover supports pump, impeller-type mixer, and liquid-level switch.

Fig. 6.5 Typical hypochlorinator installation

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

6.401 Chlorine Containers

1. *HYPOCHLORINATORS*

Plastic containers are sufficient (Figures 6.5 and 6.6). Size depends on usage. Plastic containers should be large enough to hold a two or three day's supply of hypochlorite solution. The solution should be prepared every two or three days. If a greater solution is mixed, the solution may loose its strength and thus effect the chlorine feed rate. Normally a week's supply of hypochlorite should be in storage and available for preparing hypochlorite solutions. Store the hypochlorite in a cool, dark place. Sodium hypochlorite can lose from two to four percent of its available chlorine content per month at room temperatures. Therefore, manufacturers recommend a maximum shelf life of 60 to 90 days.

2. *GAS CHLORINATORS*

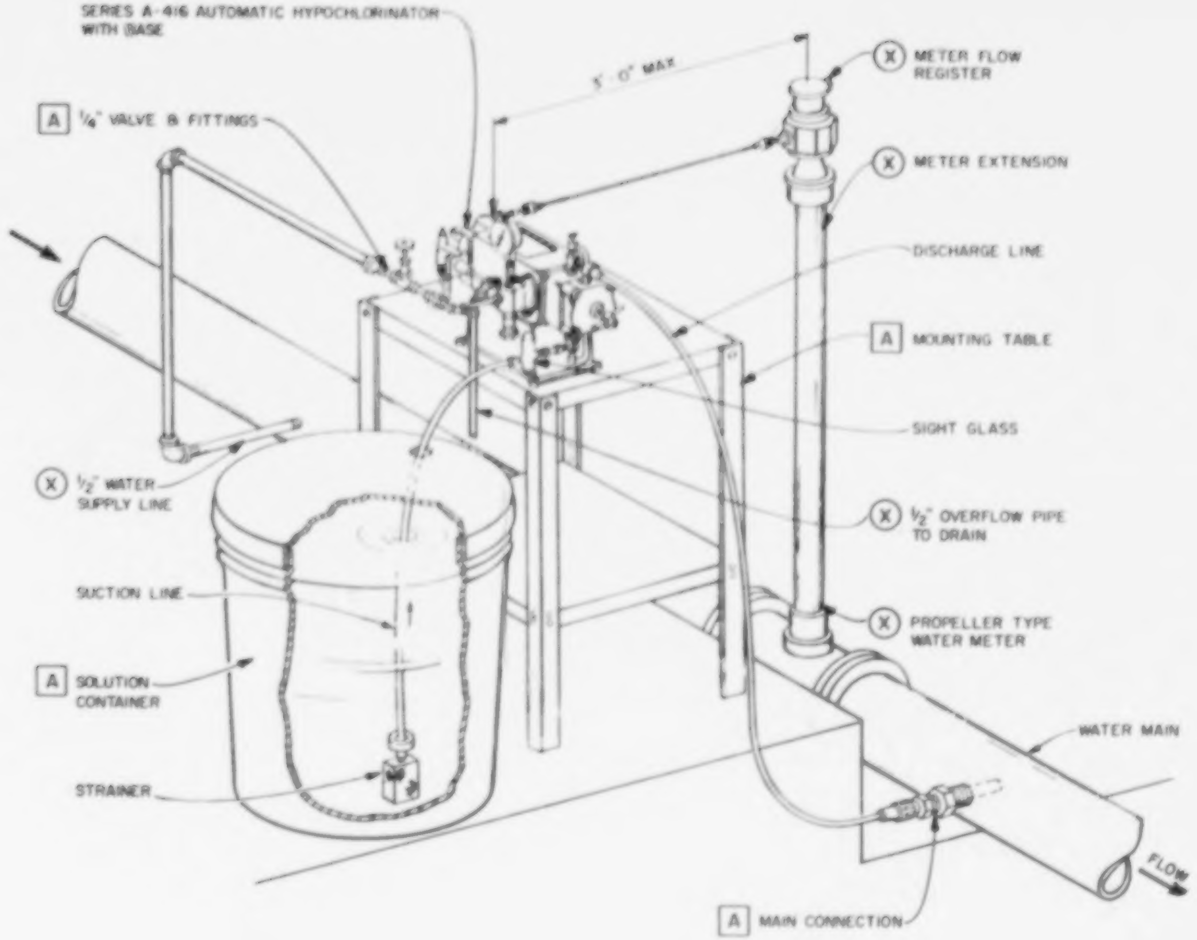
Chlorine is delivered for use by chlorinators in 100 and 150-pound (45 to 68 kg) cylinders (Figures 6.13 and 6.14), one-ton (900 kg) tanks or chlorine tank cars in sizes from 16 to 90 tons (14,500 to 81,800 kg). The 100 and 150-pound (45 to 68 kg) cylinders will be discussed in this section.

These cylinders are usually made of seamless carbon steel. A fusible plug is placed in the valve below the valve seat (Figure 6.15). This plug is a safety device. The fusible metal softens or melts at 158 to 165 degrees F (70 to 74°C) to prevent buildup of excessive pressures and the possibility of rupture due to fire or high surrounding temperatures.

The maximum rate of chlorine removal from a 150-pound (18 kg) cylinder is 40 pounds (18 kg) of chlorine per day. If the rate of removal is greater, "freezing" can occur and less chlorine will be delivered.

WARNING

When frost appears on valves and flex connectors, the chlorine gas may condense to liquid (reliquify). The liquid chlorine may plug the chlorine supply lines (sometimes this is referred to as chlorine ice or frozen chlorine). If you disconnect the chlorine supply line to unplug it, *BE VERY CAREFUL*. The liquid chlorine in the line could reevaporate, expand as a gas, build up pressure in the line, and cause liquid chlorine to come shooting out the open end of a disconnected chlorine supply line.


SERIES A-416 AUTOMATIC HYPOCHLORINATOR WITH BASE
5'-0" MAX
X METER FLOW REGISTER
A 1/4" VALVE & FITTINGS
X METER EXTENSION
DISCHARGE LINE
A MOUNTING TABLE
SIGHT GLASS
X 1/2" WATER SUPPLY LINE
X 1/2" OVERFLOW PIPE TO DRAIN
SUCTION LINE
X PROPELLER TYPE WATER METER
A SOLUTION CONTAINER
WATER MAIN
STRAINER
FLOW
A MAIN CONNECTION

Ⓧ *NOT FURNISHED BY W & T.*

[A] *ACCESSORY ITEM FURNISHED ONLY IF SPECIFICALLY LISTED IN QUOTATION AND AS CHECKED ON THIS DRAWING*

NOTE: Hypochlorinator paced by a propeller-type water meter.

Fig. 6.6 Typical hypochlorinator installation
(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

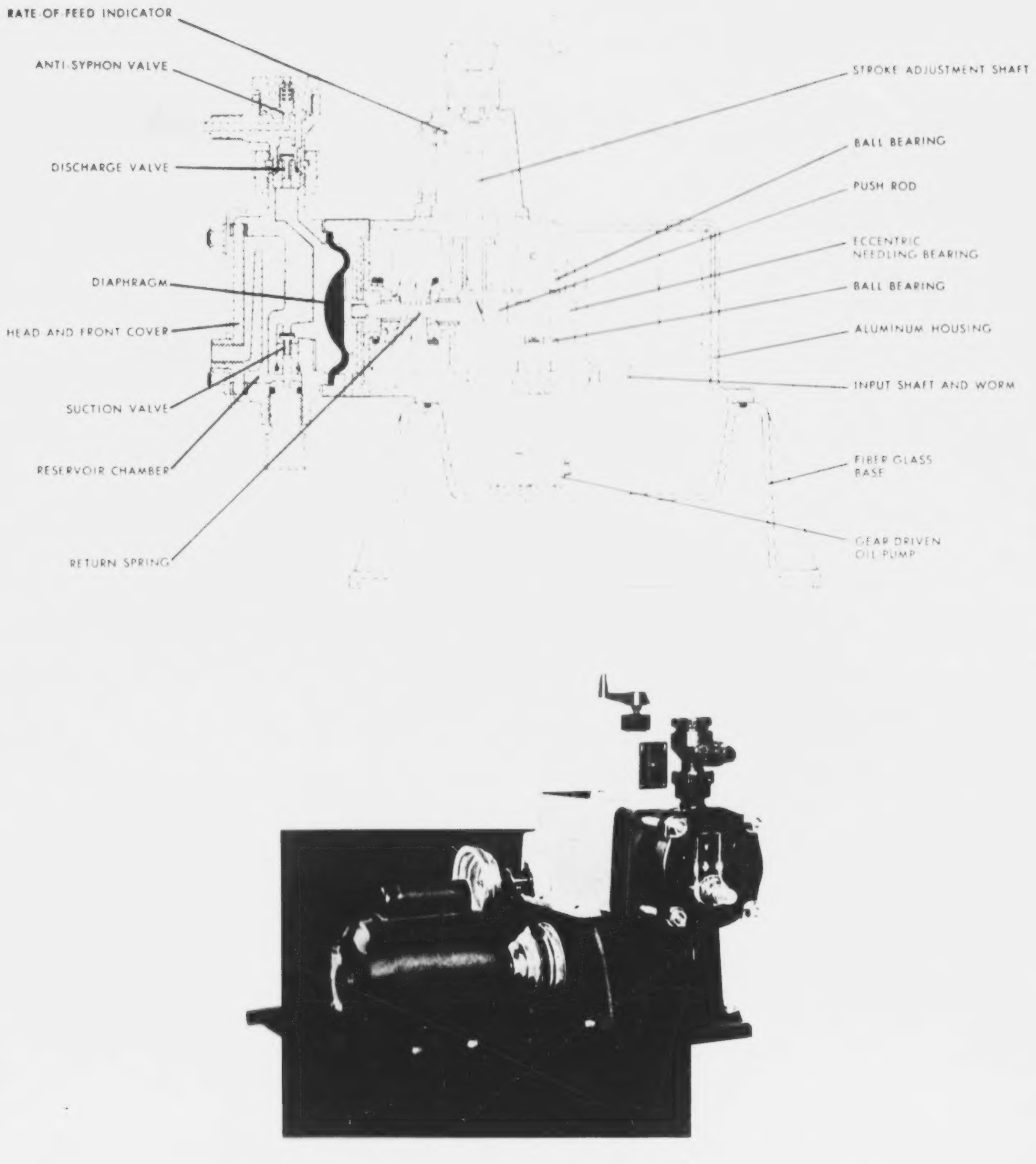

RATE-OF-FEED INDICATOR
ANTI-SYPHON VALVE
DISCHARGE VALVE
DIAPHRAGM
HEAD AND FRONT COVER
SUCTION VALVE
RESERVOIR CHAMBER
RETURN SPRING
STROKE ADJUSTMENT SHAFT
BALL BEARING
PUSH ROD
ECCENTRIC NEEDLING BEARING
BALL BEARING
ALUMINUM HOUSING
INPUT SHAFT AND WORM
FIBER GLASS BASE
GEAR DRIVEN OIL PUMP

Fig. 6.7 Diaphragm-type pump

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

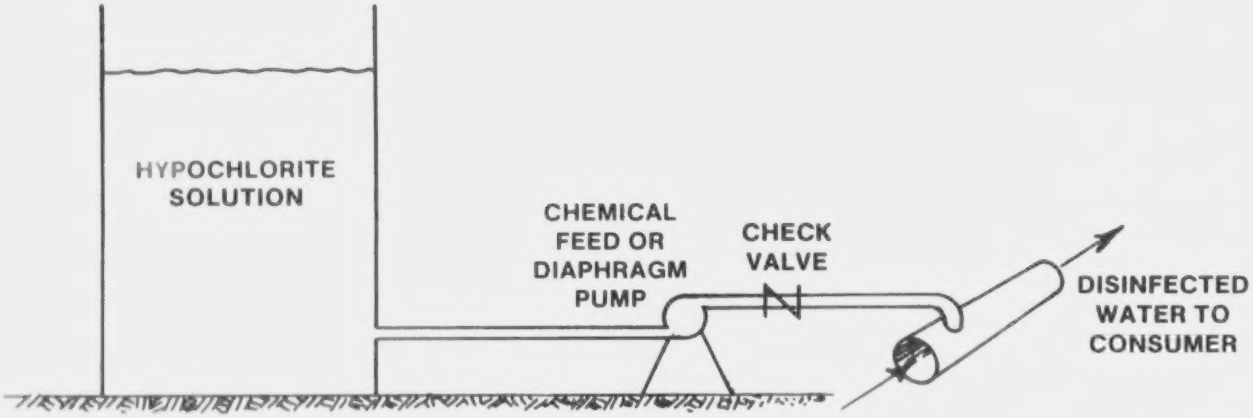
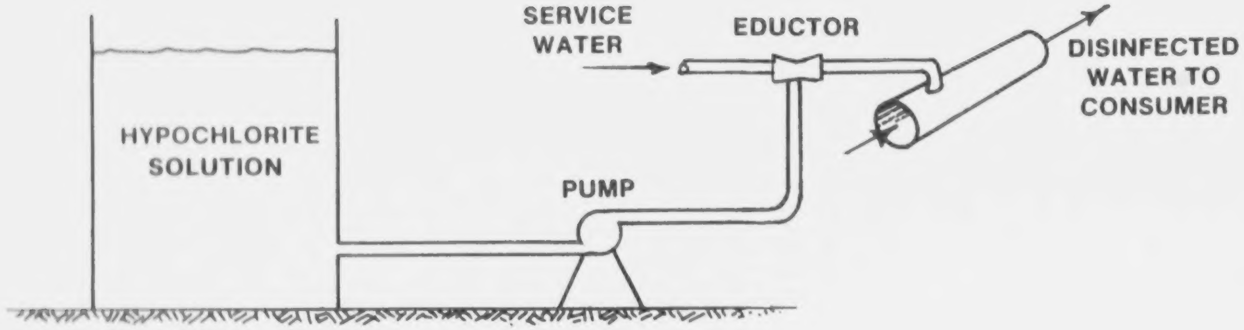

HYPOCHLORITE SOLUTION
CHEMICAL FEED OR DIAPHRAGM PUMP
CHECK VALVE
DISINFECTED WATER TO CONSUMER

Fig. 6.8 Hypochlorinator direct pumping system


SERVICE WATER
EDUCTOR
DISINFECTED WATER TO CONSUMER
HYPOCHLORITE SOLUTION
PUMP

NOTE: Pump is chemical feed or diaphragm pump

Fig. 6.9 Hypochlorinator injector feed system

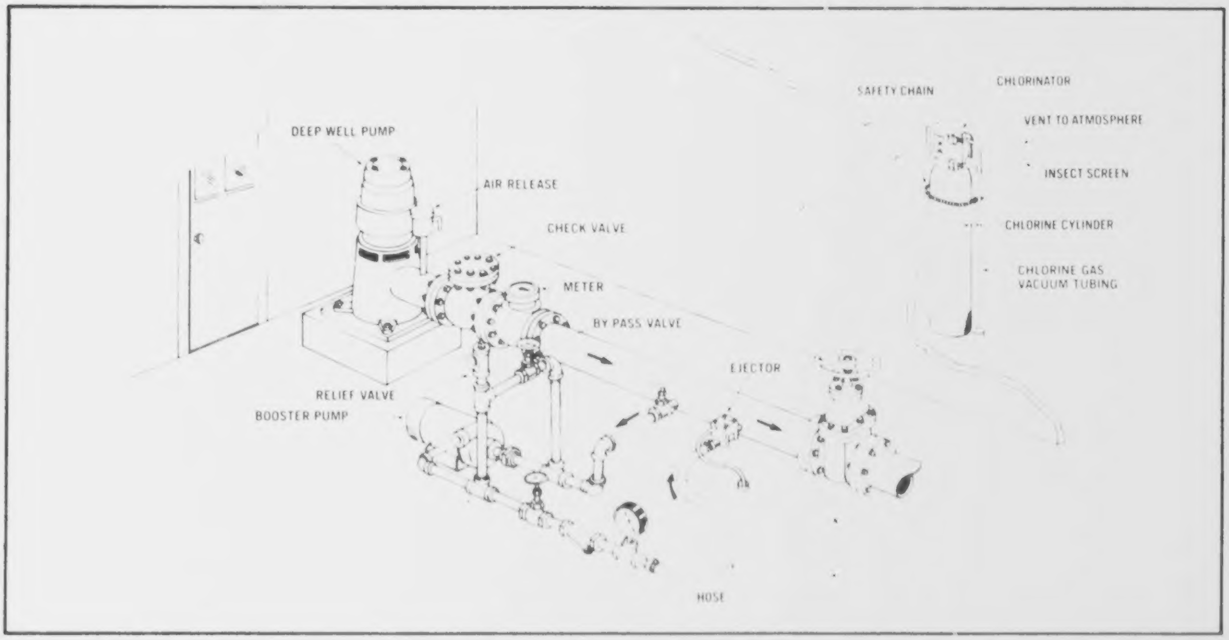

SAFETY CHAIN
CHLORINATOR
VENT TO ATMOSPHERE
INSECT SCREEN
CHLORINE CYLINDER
CHLORINE GAS VACUUM TUBING
DEEP WELL PUMP
AIR RELEASE
CHECK VALVE
METER
BY PASS VALVE
EJECTOR
RELIEF VALVE
BOOSTER PUMP
HOSE

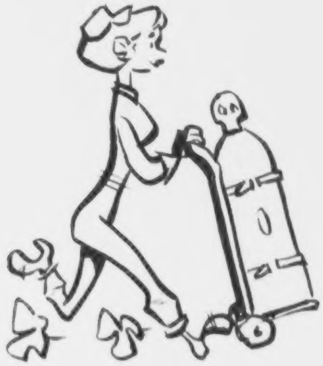
Fig. 6.10 Typical deep well chlorination system
(Permission of Capital Controls Company, Colmar, Pa.)

6.41 Chlorine Handling

Cylinders containing 100 to 150 pounds (45 to 68 kg) of chlorine are convenient for very small plants with capacities less than 0.5 MGD (1890 cu m/day or 1.89 *ML*/day).[22]

The following are procedures for safely handling chlorine cylinders.

1. Move cylinders with a properly balanced hand truck with clamp supports that fasten at least two-thirds of the way up the cylinder (Figure 6.16).



2. 100- and 150-pound (45 to 68 kg) cylinders can be rolled in a vertical position. Avoid lifting these cylinders except with approved equipment. Never lift with chains, rope slings, or magnetic hoists.
3. Always replace the protective cap when moving a cylinder.
4. Keep cylinders away from direct heat (steam pipes or radiators).
5. Store cylinders in an upright position. All empty chlorine cylinders (depressurized) must be tagged as empty.
6. Remove the outlet cap from the cylinder and inspect the threads on the outlet. Cylinders having outlet threads which are corroded, worn, cross-threaded, broken, or missing should be rejected and returned to the supplier.
7. The specifications and regulations of the U.S. Interstate Commerce Commission require that chlorine cylinders be tested at 800 psi (5516 kPa or 56.24 kg/sq cm) every five years. The date of testing is stamped on the dome of the cylinder. Cylinders which have not been tested within that period of time should be rejected and returned to the supplier.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

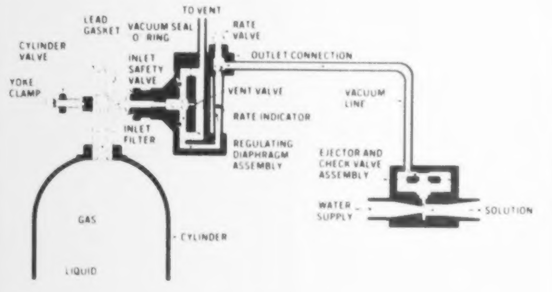
6.4A List the two major types of chlorine feeders.

6.4B Why are chlorine booster pumps needed on most well applications?

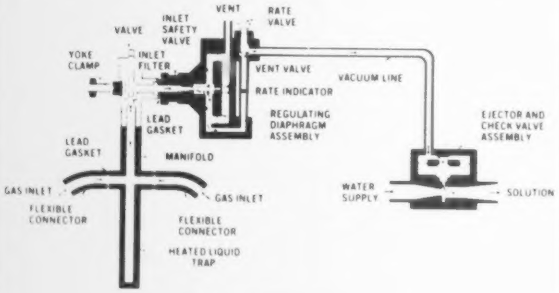
6.4C What is the maximum rate of chlorine removal from a 150-pound cylinder?

---

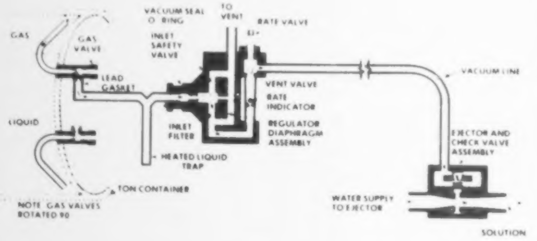
[22] *ML/day. Megaliters or million liters per day.*


TO VENT
LEAD GASKET
VACUUM SEAL O RING
RATE VALVE
CYLINDER VALVE
OUTLET CONNECTION
INLET SAFETY VALVE
YOKE CLAMP
VENT VALVE
VACUUM LINE
RATE INDICATOR
INLET FILTER
REGULATING DIAPHRAGM ASSEMBLY
EJECTOR AND CHECK VALVE ASSEMBLY
WATER SUPPLY
SOLUTION
GAS
CYLINDER
LIQUID

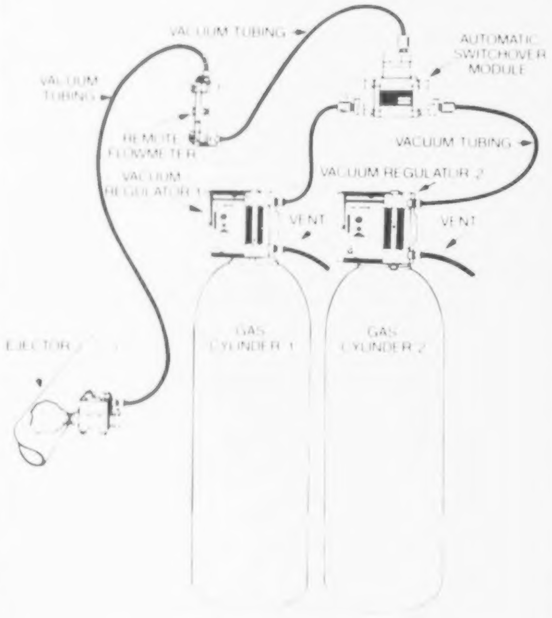
Flow Diagram
Direct Cylinder Mounted Unit


VENT
RATE VALVE
INLET SAFETY VALVE
VALVE
YOKE CLAMP
INLET FILTER
VENT VALVE
VACUUM LINE
RATE INDICATOR
LEAD GASKET
REGULATING DIAPHRAGM ASSEMBLY
EJECTOR AND CHECK VALVE ASSEMBLY
LEAD GASKET
MANIFOLD
WATER SUPPLY
SOLUTION
GAS INLET
GAS INLET
FLEXIBLE CONNECTOR
FLEXIBLE CONNECTOR
HEATED LIQUID TRAP

Flow Diagram
Manifold Mounted Unit


VACUUM SEAL O RING
TO VENT
RATE VALVE
GAS
GAS VALVE
INLET SAFETY VALVE
VACUUM LINE
LEAD GASKET
VENT VALVE
RATE INDICATOR
LIQUID
INLET FILTER
REGULATOR DIAPHRAGM ASSEMBLY
EJECTOR AND CHECK VALVE ASSEMBLY
HEATED LIQUID TRAP
TON CONTAINER
NOTE GAS VALVES ROTATED 90
WATER SUPPLY TO EJECTOR
SOLUTION

Flow Diagram
Ton Container Mounted Unit


VACUUM TUBING
AUTOMATIC SWITCHOVER MODULE
VACUUM TUBING
REMOTE FLOWMETER
VACUUM TUBING
VACUUM REGULATOR 1
VACUUM REGULATOR 2
VENT
VENT
EJECTOR
GAS CYLINDER 1
GAS CYLINDER 2

Automatic Switchover Operation
100 PPD (2000 g/hr) Cylinder Mounted System Shown

Fig. 6.11 Typical chlorinator flow diagrams
(Permission of Capital Controls Company, Colmar, Pa.)

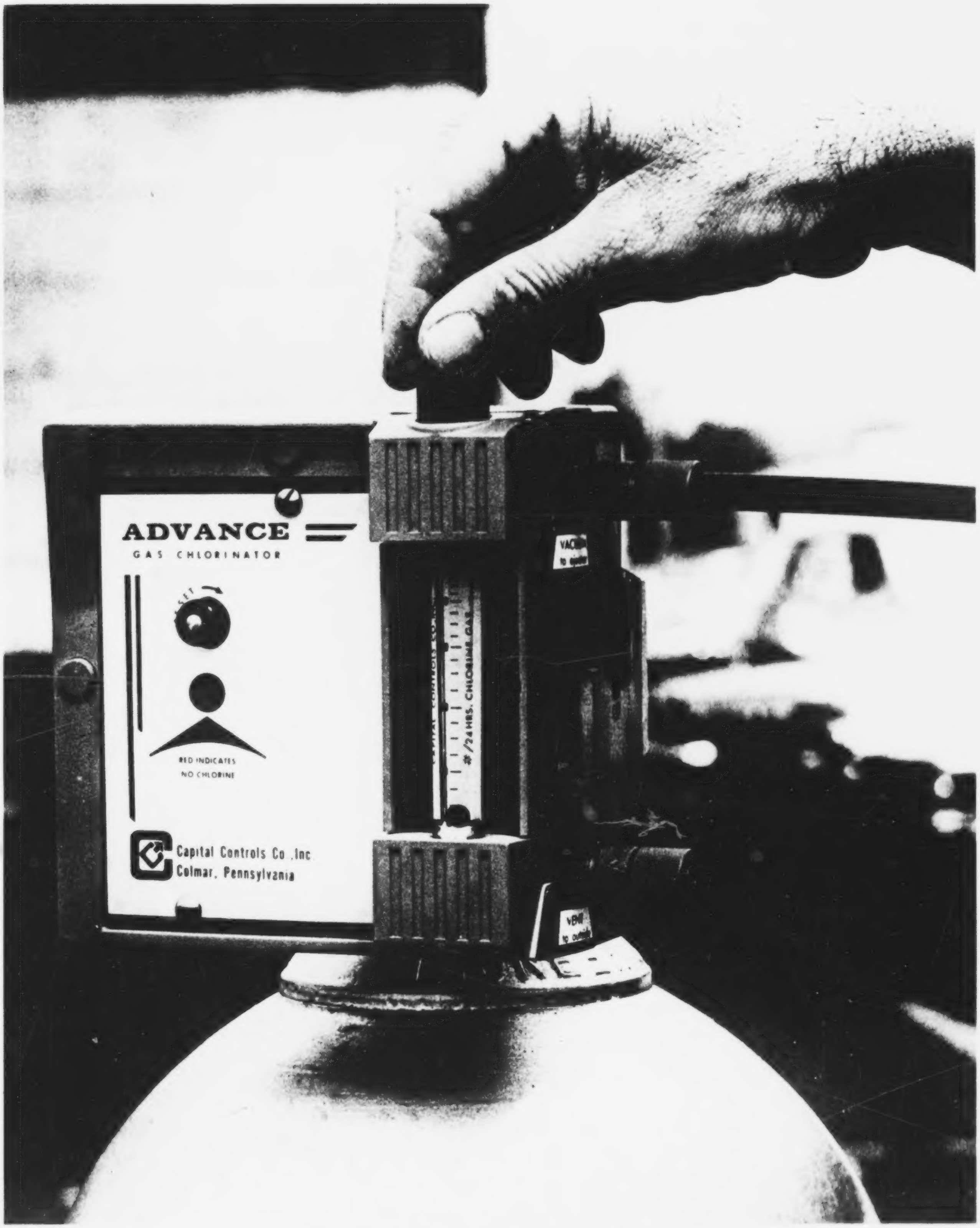
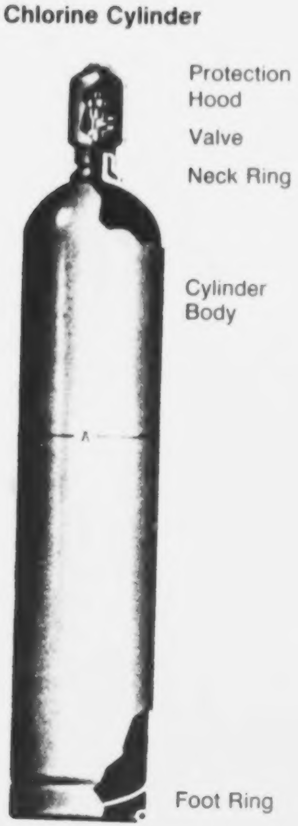

ADVANCE
GAS CHLORINATOR
SET
RED INDICATES
NO CHLORINE
Capital Controls Co.,Inc
Colmar, Pennsylvania
#/24 HRS. CHLORINE GAS
VACUUM
to ejector
VENT
to outside

Fig. 6.12 Chlorinator with rotameter showing feed rate in #/24 hrs chlorine gas

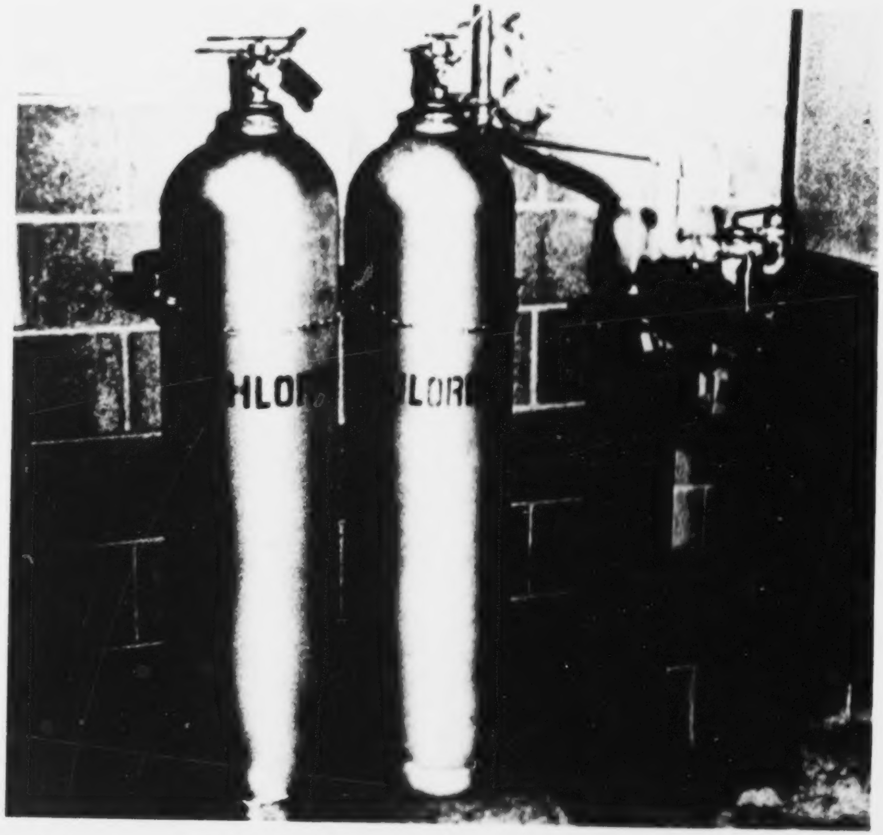
(Permission of Capital Controls Company, Colmar, Pa.)


Chlorine Cylinder
Protection Hood
Valve
Neck Ring
Cylinder Body
A
Foot Ring

Net Cylinder Contents	Approx. Tare, Lbs. *	Dimensions, Inches	
		A	B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¼	54½

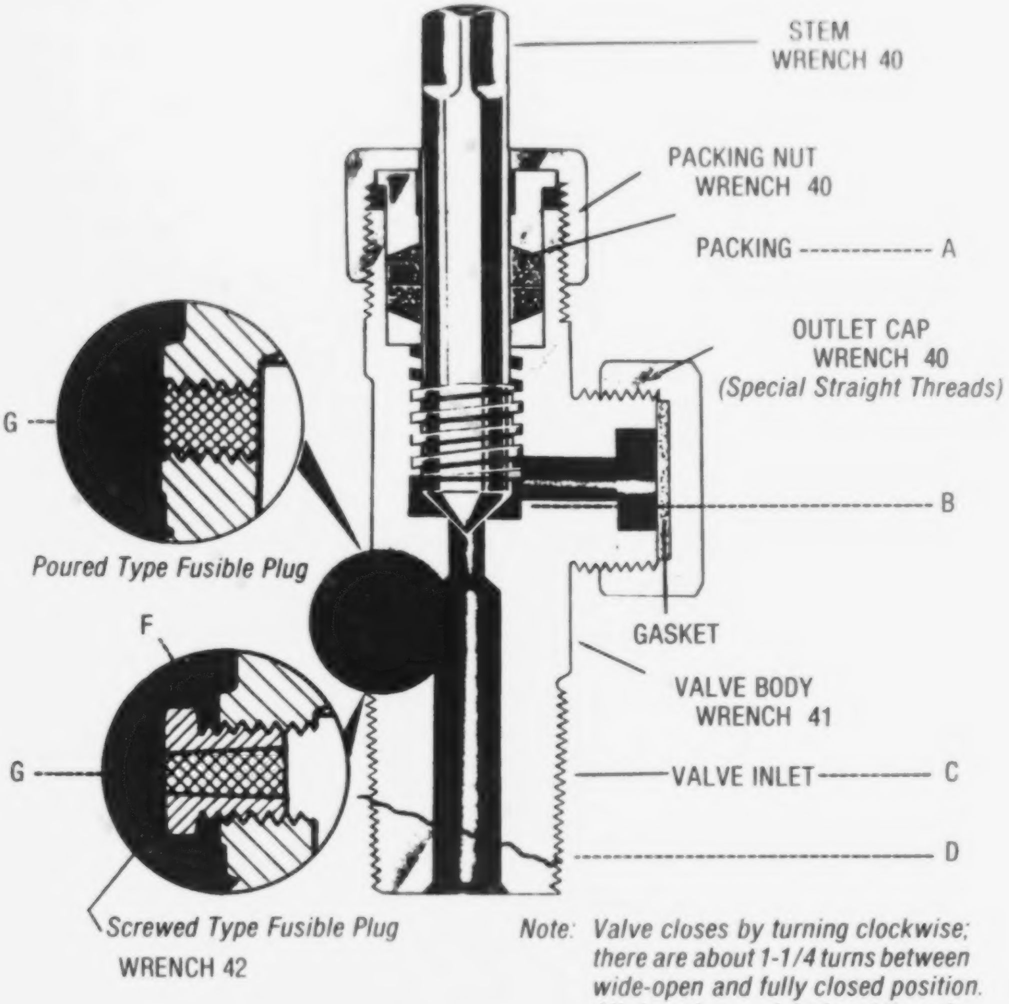
*Stamped tare weight on cylinder shoulder does not include valve protection hood.

Fig. 6.13 Chlorine cylinder
(Courtesy of PPG Industries)


CHLORI
CHLORI

NOTES:
1. Scale for weighing chlorine cylinders and chlorine.
2. Flexible tubing (pig tail).
3. Cylinders chained to wall.

Fig. 6.14 Typical chlorine cylinder station for water treatment
(Courtesy of PPG Industries)


STEM
WRENCH 40
PACKING NUT
WRENCH 40
PACKING ------------- A
OUTLET CAP
WRENCH 40
(Special Straight Threads)
G
B
Poured Type Fusible Plug
F
GASKET
VALVE BODY
WRENCH 41
G
VALVE INLET---------- C
D
Screwed Type Fusible Plug
WRENCH 42

Note: Valve closes by turning clockwise; there are about 1-1/4 turns between wide-open and fully closed position. All threads are right-hand threads.

TYPICAL VALVE LEAKS OCCUR THROUGH . . .

A - VALVE PACKING GLAND
B - VALVE SEAT
C - VALVE INLET THREADS
D - BROKEN OFF VALVE
E - VALVE BLOWN OUT
F - FUSIBLE PLUG THREADS
G - FUSIBLE METAL OF PLUG
H - VALVE STEM BLOWN OUT

Fig. 6.15 Standard chlorine cylinder valve
(Permission of Chlorine Specialties, Inc.)

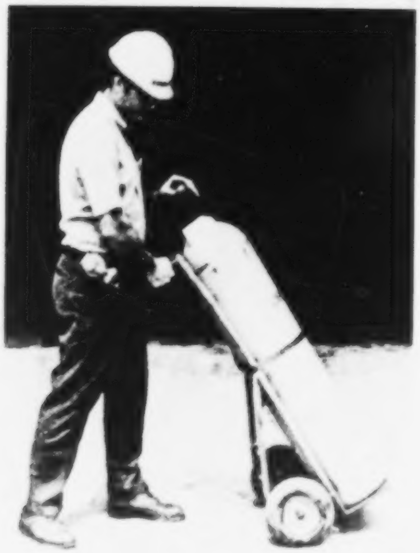


Fig. 6.16 Hand truck for chlorine cylinder
(Courtesy of PPG Industries)

6.42 Performance of Chlorination Units

6.420 Hypochlorinators

1. *HYPOCHLORINATOR STARTUP*

   a. Solution. Chemical solutions have to be made up. Most agencies buy commercial or industrial hypochlorite at around 12 to 15 percent chlorine. This solution is usually diluted down to a two percent solution. If using commercially prepared solutions, dosage rates will have to be calculated.

   b. Electrical. Lock out the circuit while making an inspection of an electrical circuit. Normally no adjustments are needed. Look for frayed wires. Turn the power back on. Leave the solution switch off.

   c. Turn the chemical pump on. Make any necessary adjustments while the pump is running. Never adjust the pump while it is off because damage to the pump will occur.

   d. Make sure the solution is being fed into system.

   e. Check the chlorine residual in the system. Residual should be at least 0.2 mg/*L* throughout the distribution system. Adjust the chemical feed as required.

2. *HYPOCHLORINATOR SHUTDOWN*

   a. Short Duration

      (1) Turn the water supply pump off. You do not want to pump any unchlorinated water and possibly contaminate the rest of the system.

      (2) Turn the hypochlorinator off.

      (3) When making any repairs, lock out the circuit or pull the plug from an electric socket.

   b. Long Duration

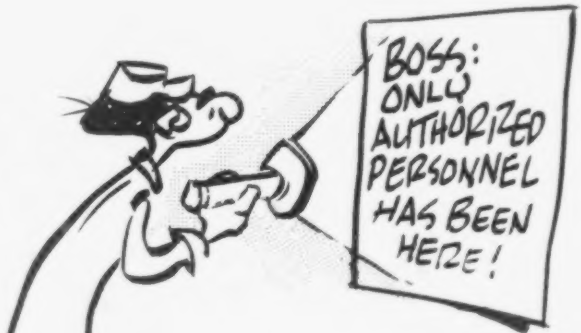
      (1) Obtain another hypochlorinator as a replacement.

3. *NORMAL OPERATION OF HYPOCHLORINATOR*

Normal operation of the hypochlorination process requires routine observation and preventive maintenance.

DAILY

   a. Inspect the building to make sure only authorized personnel have been there.


BOSS: ONLY AUTHORIZED PERSONNEL HAS BEEN HERE!

   b. Read and record the level of the solution tank at the same time every day.

   c. Read the meters and record the amount of water pumped.

d. Check the chlorine residual (0.2 mg/*L*) in the system and adjust the chlorine feed rate as necessary. Try to maintain a chlorine residual of 0.2 mg/*L* at the most remote point in the distribution system. The suggested free chlorine residual for treated water or well water is 0.5 mg/*L* at the point of chlorine application provided the 0.2 mg/*L* is maintained throughout the distribution system.

e. Check the chemical feed pump operation. Most hypochlorinators have a dial with a range from 0 to 10 which indicates the chlorine feed rate. Initially set the pointer on the dial to approximately 6 or 7 on the dial and use a two percent hypochlorite solution. The pump should be operated in the upper ranges of the dial. This will require the frequency of the strokes or pulses from the pump to be frequent enough so that the chlorine will be fed continuously to the water being treated. Adjust feed rate after testing chlorine residual levels.

WEEKLY

a. Clean the building.

b. Replace the chemicals and wash the chemical storage tank. Try to have a 15 to 30-day supply of chlorine in storage for future needs. When preparing hypochlorite solutions, prepare only enough for a two or three-day supply.

MONTHLY

a. Check the operation of the check valve.

b. Perform any required preventive maintenance.

c. Cleaning

Commercial sodium hypochlorite solutions (such as chlorox) contain an excess of caustic (sodium hydroxide or NaOH). When this solution is diluted with water containing calcium and also carbonate alkalinity, the resulting solution becomes supersaturated with calcium carbonate. This calcium carbonate tends to form a coating on the poppet valves in the solution feeder. The coated valves will not seal properly and the feeder will fail to feed properly.

Use the following procedure to remove the carbonate scale:

(1) Fill a one quart (one liter) Mason jar half full of tap water.

(2) Place one fluid ounce (20 mL) of 30 to 37 percent hydrochloric acid (swimming pool acid) in the jar. ALWAYS ADD ACID TO WATER, NEVER THE REVERSE.

(3) Fill the jar with tap water.

(4) Place the suction hose of the hypochlorinator in the jar and pump the entire contents of the jar through the system.

(5) Return the suction hose to the hypochlorite solution tank and resume normal operation.

You can prevent the formation of the calcium carbonate coatings by obtaining the dilution water from an ordinary home water softener.

NORMAL OPERATION CHECKLIST

a. Check chemical usage. Record solution level and the water pump meter reading or number of hours of pump operation. Calculate the amount of chemical solution used and compare with the desired feed rate. See EXAMPLE 4.

b. Determine if every piece of equipment is operating.

c. Inspect the lubrication of the equipment.

d. Check the building for any possible problems.

e. Clean up the area.

FORMULAS

To determine the actual chlorine dose of water being treated by either a chlorinator or a hypochlorinator, we need to know the gallons of water treated and the pounds of chlorine used to disinfect the water.

1. Calculate the pounds of water disinfected.

$$\text{Water, lbs} = (\text{Water Pumped, gallons})(8.34\ \text{lbs/gal})$$

2. To calculate the volume of hypochlorite used from a container, we need to know the dimensions of the container.

$$\text{Volume, gallons} = \frac{(0.785)(\text{Diameter, in})^2(\text{Depth, ft})(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

3. To calculate the pounds of chlorine used to disinfect water, we need to know the gallons of hypochlorite used and the percent available chlorine in the hypochlorite solution.

$$\text{Chlorine, lbs} = (\text{Hypochlorite, gal})(8.34\ \text{lbs/gal})\left(\frac{\text{Hypochlorite, \%}}{100\%}\right)$$

4. To determine the actual chlorine dose in milligrams per liter, we divide the pounds of chlorine used by the millions of pounds of water treated. Pounds of chlorine per million pounds of water is the same as parts per million or milligrams per liter.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine Used, lbs}}{\text{Water Treated, Million lbs}}$$

EXAMPLE 4

Water pumped from a well is disinfected by a hypochlorinator. A chlorine dosage of 1.2 mg/*L* is necessary to maintain an adequate chlorine residual throughout the system. During a one-week time period, the water meter indicated that 2,289,000 gallons of water were pumped. A two-percent sodium hypochlorite solution is stored in a three-foot diameter plastic tank. During this one-week period, the level of hypochlorite in the tank dropped 2 feet, 8 inches (2.67 feet). Does the chlorine feed rate appear to be too high, too low or about right?

Known

Desired Chlorine Dose, mg/L = 1.2 mg/L
Water Pumped, gal = 2,289,000 gal
Hypochlorite, % = 2%
Chemical Tank Diameter, ft = 3 ft
Chemical Drop in Tank, ft = 2.67 ft

Unknown

1. Actual Chlorine Dose, mg/L
2. Is Actual Dose OK?

KNOWN
UNKNOWN

1. Calculate the pounds of water disinfected.

$$\begin{aligned}\text{Water, lbs} &= (\text{Water Pumped, gallons})(8.34\text{ lbs/gal})\\ &= (2{,}289{,}000\text{ gal})(8.34\text{ lbs/gal})\\ &= 19{,}090{,}000\text{ lbs}\\ &= 19.09\text{ Million lbs}\end{aligned}$$

2. Calculate the volume of 2 percent sodium hypochlorite used in gallons.

$$\begin{aligned}\text{Hypochlorite, gallons} &= (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\text{ gal/cu ft})\\ &= (0.785)(3\text{ ft})^2(2.67\text{ ft})(7.48\text{ gal/cu ft})\\ &= 141.1\text{ gallons}\end{aligned}$$

3. Determine the pounds of chlorine used to disinfect the water.

$$\begin{aligned}\text{Chlorine lbs} &= (\text{Hypochlorite, gal})(8.34\text{ lbs/gal})\left(\frac{\text{Hypochlorite, \%}}{100\%}\right)\\ &= (141.1\text{ gal})(8.34\text{ lbs/gal})\left(\frac{2\%}{100\%}\right)\\ &= 23.5\text{ lbs chlorine}\end{aligned}$$

4. Calculate the chlorine dosage in mg/L.

$$\begin{aligned}\text{Chlorine Dose, mg/}L &= \frac{\text{Chlorine Used, lbs}}{\text{Water Treated, Million lbs}}\\ &= \frac{23.5\text{ lbs chlorine}}{19.09\text{ Million lbs water}}\\ &= 1.23\text{ mg/}L\end{aligned}$$

Since actual chlorine dose (1.23 mg/*L*) was slightly greater than the desired dose of 1.2 mg/*L*, the chlorine feed rate appears OK.

4. *ABNORMAL OPERATION OF HYPOCHLORINATOR*

a. Inform your Supervisor of the problem.

b. If the hypochlorinator malfunctions, it should be repaired immediately. See the shutdown operation (Step 2 in this section).

c. Solution tank level.

(1) If Too Low — Check the adjustment of the pump.
Check the hour meter of the water pump.

(2) If Too High — Check the chemical pump.
Check the hour meter of the water pump.

d. Determine if the chemical pump is not operating.

TROUBLESHOOTING GUIDELINES

ELECTRICAL CONNECTION

(1) Check the electrical connection.
(2) Check the circuit breaker.
(3) Check for stoppages in the flow lines.

CORRECTIVE MEASURES

(1) Shut off the water pump so that no contaminated water is pumped into the system.
(2) Check for a blockage in the solution tank.
(3) Check the operation of the check valve.
(4) Check the electrical circuits.
(5) Replace the chemical feed pump with another pump while repairing the defective unit.

e. The solution is not being pumped into the water line.

TROUBLESHOOTING GUIDELINES

(1) Check the solution level.
(2) Check for blockages in the solution line.

5. *MAINTENANCE OF HYPOCHLORINATORS*

Hypochlorinators on small systems are normally small, sealed systems that cannot be repaired so replacement of the entire unit is the only solution. Maintenance requirements are normally minor such as changing the oil and lubricating the moving parts. Review the manufacturer's specifications for maintenance requirements.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.4D What is the basis for adjusting the chemical feed of a hypochlorinator?

6.4E When should the level of the hypochlorite solution tank be read?

6.4F What is the basis for determining the strength of the hypochlorite solution in the solution tank?

6.4G What maintenance is usually required of hypochlorinators?

6.421 Chlorinators

1. *SAFETY EQUIPMENT REQUIRED AND AVAILABLE OUTSIDE THE CHLORINATOR ROOM*
   a. Protective clothing
      (1) Gloves
      (2) Rubber suit
   b. Self-contained pressure-demand air supply system (Figure 6.17)

2. *STARTUP OF CHLORINATORS*

Work in pairs. Never work alone when hooking up a chlorine system.

a. Inspect the chlorine container for leaks.

b. Inspect the chlorination equipment.

c. Use new gaskets for hookup of the chlorinator to supply containers. Gaskets should be stored in a refrigerator or other cool, dark place so they won't deteriorate before you want to use them.

d. Prior to the hookup, inspect for moisture and foreign substances in the lines.

e. Have an ammonia bottle readily available to detect any leaks in the system. Dip a rag on the end of a stick in the ammonia[23] bottle and place the rag near the location of suspected leaks. A white cloud will reveal the location of a chlorine leak.

f. Have safety equipment available which may be used in case of a leak.

g. Hook up the chlorinator to the chlorine container with the chlorine valve turned off. Use the gas side (not liquid side) if using a ton tank.

h. Open the chlorine valve slightly and check for leaks. Remember — don't leave the valve in this position for a long time because it will plug up. Commercial chlorine usually contains small amounts of chlorinated organic compounds which are not volatile. Trace amounts of these compounds can be carried over in the chlorine vapor. A slightly opened valve, with the resulting change in velocity, is an ideal place for these materials to collect, build up and cause the valve to plug up. Open the valve to prevent plugging.

i. Adjust the chlorinator to the proper setting. The desired chlorine residual should be maintained throughout the distribution system. Coliform test results should be negative when the chlorination system is operating properly.

3. *CHLORINATOR SHUTDOWN*

Work in pairs. A plan should be used where both people are not exposed to the chlorine at the same time.

a. Have safety equipment available in the event of a chlorine leak.

b. Shut off the chlorine valve from the supply source.

c. Allow sufficient time for the chlorine to purge out of the line.

d. Turn the chlorinator off.

e. Leave the discharge line open. If chlorine is trapped between two valves, the chlorine gas can expand when heated by sunlight and develop high pressures in the line. Leave the discharge line open to prevent this hazard from developing.

4. *NORMAL OPERATION OF CHLORINATORS*

Normal operation of a chlorinator requires routine observation and preventive maintenance.

DAILY

a. Inspect the building to make sure that only authorized personnel have been there.

b. Read the chlorinator rotameter.

c. Record the reading, time, date and initial the entries.

d. Read the meters and record the number of gallons of water pumped.

e. Check the chlorine residual. If the residual is below 0.2 mg/*L* in the distribution system, increase the feed rate by adjusting the rotameter. If the residual is too high, lower the feed rate by adjusting the rotameter.

f. Calculate the chlorine usage. Refer to EXAMPLES 5 and 6.

WEEKLY

a. Clean the equipment and the building.

b. Perform preventive maintenance on the equipment.

Chlorine usage should be calculated so that replacement supply containers can be ordered and constant chlorination can be maintained. Refer to EXAMPLE 7. Try to have a 15 to 30-day supply of chlorine in storage.

NORMAL OPERATION CHECKLIST

a. Chemical usage in pounds.

b. Meter readings for water usage in gallons.

c. Equipment log.

d. Lubrication inspection log.

e. Building inspection.

5. *ABNORMAL OPERATION*

a. Inform supervisor of the problem.

b. If the chlorinator malfunctions, repair the unit immediately.

---

[23] *Use a concentrated ammonia solution containing 28 to 30 percent ammonia as NH_3 (this is the same as 58 percent ammonium hydroxide, NH_4OH, or commercial 26° Baume).*

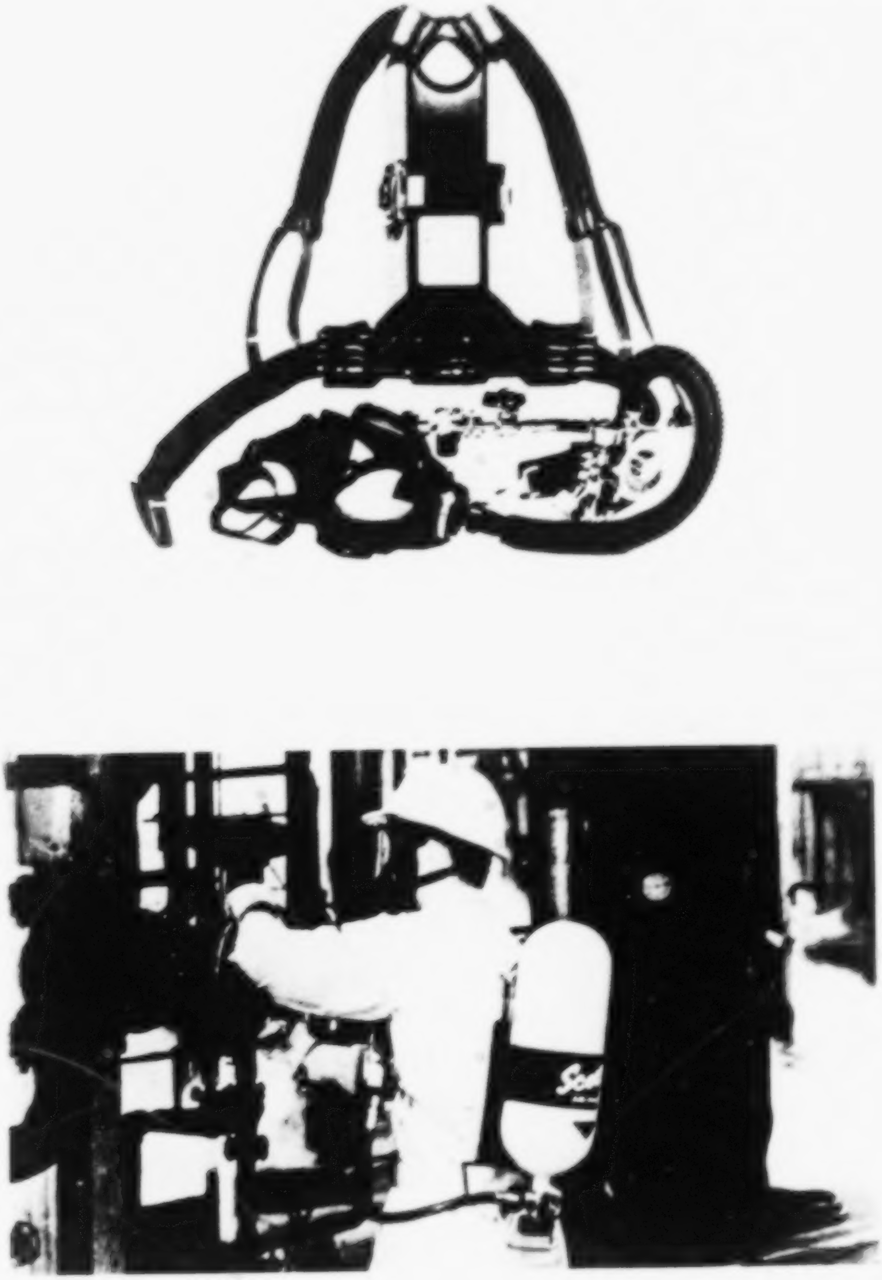


Fig. 6.17 Self-contained breathing apparatus

(Courtesy of PPG Industries)

c. If repairs cannot be completed quickly, shut off the water supply so that unchlorinated or contaminated water will not be delivered to the consumers.

ABNORMAL OPERATION, TROUBLESHOOTING

a. Chlorine not feeding. Troubleshooting

   (1) Check the chlorine supply system.
   (2) Check the electrical system.
   (3) Check for blockages in line.

6. *MAINTENANCE*

Most chlorinators are simple units and are more easily replaced than repaired on-line. Remove and repair in shop or have repaired by others who do not have to operate the system.

FORMULAS

To determine the setting on a chemical feeder in pounds per day, multiply the flow in MGD times the dose in mg/*L* times 8.34 lbs/gal.

$$\text{Feeder Setting, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

To calculate the number of chlorine cylinders used per month, determine the pounds of chlorine used per month and divide by the pounds of chlorine per cylinder.

$$\text{Cylinders Used, number/month} = \frac{\text{Chlorine Used, lbs/mo}}{\text{Chlorine Cylinders, lbs/cylinder}}$$

EXAMPLE 5

A deep-well turbine pump delivers approximately 200 GPM against typical operating heads. If the desired chlorine dose is 2 mg/*L*, what should be the setting on the rotameter for the chlorinator (lbs chlorine per 24 hours)?

Known	Unknown
Pump Flow, GPM = 200 GPM	Rotameter Setting, lbs chlorine/24 hours
Chlorine Dose, mg/*L* = 2 mg/*L*	

1. Convert pump flow to million gallons per day (MGD).

$$\text{Flow, MGD} = \frac{(200\ \text{GPM})(1\ \text{Million})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000}$$

$$= 0.288\ \text{MGD}$$

2. Calculate the rotameter setting in pounds of chlorine per 24 hours.

$$\begin{aligned}\text{Rotameter Setting, lbs/day} &= (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})\\ &= (0.288\ \text{Mil Gal/day})(2\ \text{mg}/L)(8.34\ \text{lbs/gal})\\ &= 4.8\ \text{lbs/day}\\ &= 4.8\ \text{lbs/24 hours}\end{aligned}$$

EXAMPLE 6

Using the results from EXAMPLE 5 (a chlorinator setting of 4.8 lbs/day), how many pounds of chlorine would be used during one week if the pump hour meter showed 100 hours of pump operation? If the chlorine cylinder contained 78 pounds of chlorine at the start of the week, how many pounds of chlorine should be remaining at the end of the week?

Known	Unknown
Chlorinator Setting, lbs/day = 4.8 lbs/day	1. Chlorine Used, lbs/week
Time, hrs/week = 100 hr/week	2. Chlorine Remaining, lbs
Chlorine Cylinder, lbs = 78 lbs	

1. Calculate the chlorine used in pounds per week.

$$\begin{aligned}\text{Chlorine Used, lbs/week} &= (\text{Chlorinator Setting, lbs/day})(\text{Time, hrs/week})\\ &= (4.8\ \text{lbs/day})\left(\frac{100\ \text{hrs/wk}}{24\ \text{hrs/day}}\right)\\ &= 20\ \text{lbs chlorine/week}\end{aligned}$$

2. Determine the amount of chlorine that should be remaining in the cylinder at the end of the week.

$$\begin{aligned}\text{Chlorine Remaining lbs} &= \text{Chlorine at Start, lbs} - \text{Chlorine Used, lbs}\\ &= 78\ \text{lbs} - 20\ \text{lbs}\\ &= 58\ \text{lbs chlorine remaining at end of week}\end{aligned}$$

EXAMPLE 7

Given the pumping rate and chlorination system in EXAMPLES 5 and 6. If 20 pounds of chlorine are used during an average week, how many 150-pound chlorine cylinders will be used per month (assume 30 days per month).

Known	Unknown
Chlorine Use, lbs/week = 20 lbs/week	1. Amount of Chlorine Used per Month, lbs
	2. Number of 150-lb Cylinders Used per Month

1. Calculate the amount of chlorine used in pounds of chlorine per month.

$$\begin{aligned}\text{Chlorine Used, lbs/month} &= (\text{Chlorine Use, lbs/week})(\text{Number Weeks/mo})\\ &= (20\ \text{lbs/week})\left(\frac{(1\ \text{week})(30\ \text{days})}{(7\ \text{days})(1\ \text{month})}\right)\\ &= 85.7\ \text{lbs/month}\end{aligned}$$

2. Determine the number of 150-pound chlorine cylinders used per month.

$$\begin{aligned}\text{Cylinders Used, number/month} &= \frac{\text{Chlorine Used, lbs/mo}}{\text{Chlorine Cylinders, lbs/cylinder}}\\ &= \frac{85.7\ \text{lbs/mo}}{150\ \text{lbs/cylinder}}\\ &= 0.57\ \text{cylinders/month}\end{aligned}$$

This installation requires less than one 150-pound chlorine cylinder per month.

6.43 Laboratory Tests

1. Chlorine residual in system

   a. Daily chlorine residual tests using the *DPD*[24] *METHOD*[25] should be taken at various locations in the system. A remote tap is ideal for one sampling location. Take the test sample from a tap as close to the main as possible. Allow the water to run at least 5 minutes before sampling to assure a representative sample from the main.

---

[24] *DPD. A method for measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. DPD stands for N, N-diethyl-p-phenylene-diamine.*

[25] *See Section 6.5, "Measurement of Chlorine Residual," for details on how to perform the DPD test for measuring chlorine residual.*

b. Chlorine residual test kits are available for small systems.

2. Bacteriological Analysis (Coliform Tests)

Samples should be taken routinely in accordance with health department requirements. Take samples according to approved procedures.[26] Be sure to use a sterile plastic or glass bottle. If the sample contains any chlorine residual, sufficient sodium thiosulfate should be added to neutralize all of the chlorine residual. Usually 0.1 milliliter of 10 percent sodium thiosulfate in a 120 m*L* (4 oz) bottle is sufficient for distribution systems. The "thio" should be added to the sample bottle before sterilization.

6.44 Troubleshooting

TABLE 6.7 DISINFECTION TROUBLESHOOTING GUIDE

Operating Symptoms	Probable Cause	Remedy
1. Increase in coliform level	Low chlorine residual	Raise chlorine dose
2. Drop in chlorine level	a. Increase in chlorine demand b. Drop in chlorine feed rate	Raise chlorine dose and find out why chlorine demand increased or chlorine feed rate dropped

6.45 Chlorination System Failure

IF YOUR CHLORINATION SYSTEM FAILS, DO NOT ALLOW UNCHLORINATED WATER TO ENTER THE DISTRIBUTION SYSTEM. Never allow unchlorinated water to be delivered to your consumers. If your chlorination system fails and cannot be repaired within a reasonable time period, notify your supervisor and officials of the health department. To prevent this problem from occurring, your plant should have backup or standby chlorination facilities.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 336.

6.4H What personal safety equipment should be available before attempting to locate and repair a chlorine gas leak?

6.4I How is ammonia used to detect a chlorine leak?

6.4J What would you do if you could not repair a broken chlorinator quickly?

6.4K What two water quality tests are most commonly run on samples of water from a water supply system?

6.5 MEASUREMENT OF CHLORINE RESIDUAL

6.50 Methods of Measuring Chlorine Residual

AMPEROMETRIC TITRATION[27] provides for the most convenient and most repeatable chlorine residual results. However, amperometric titration equipment is more expensive than equipment for other methods. DPD tests can be used and are less expensive than other methods, but this method requires the operator to match the color of a sample with the colors on a comparator. See Chapter 7, "Laboratory Procedures" in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE*, for detailed information on these tests.

Residual chlorine measurements of treated water should be taken at least three times per day on small systems and once every two hours on large systems. Residuals are measured to insure that the treated water is being adequately disinfected. A free chlorine residual of at least 0.5 mg/*L* in the treated water is usually recommended.

6.51 Amperometric Titration for Free Residual Chlorine

1. Place a 200 m*L* sample of water in the titrator.
2. Start the agitator.
3. Add 1 m*L* of pH 7 buffer.
4. Titrate with 0.00564 *N* phenylarsene oxide solution.
5. End point is reached when one drop will cause a deflection on the microammeter and the deflection will remain.
6. m*L* of phenylarsene oxide used in titration is equal to mg/*L* of free chlorine residual.

6.52 DPD Colorimetric Method for Free Residual Chlorine (Figures 6.18 and 6.19)

This procedure is for the use of prepared powder pillows.

1. Collect a 100 m*L* sample.
2. Add color reagent.
3. Match color sample with a color on the comparator to obtain the chlorine residual in mg/*L*.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 337.

6.5A What two methods are commonly used to measure chlorine residual in treated water?

6.5B How often should treated water residual chlorine measurements be made?

6.6 CHLORINE SAFETY PROGRAM

Every good safety program begins with cooperation between the employee and the employer. The employee must take an active part in the overall program. The employee must be responsible and should take all necessary steps to prevent accidents. This begins with the attitude that as good an effort as possible must be made by everyone. Safety is everyone's problem. The employer also must take an active part by supporting safety programs. There must be funding to purchase equipment and to enforce safety regulations required by OSHA and state industrial safety programs. The following items should be included in all safety programs.

1. Establishment of a formal safety program.
2. Written rules.
3. Periodic hands-on training using safety equipment.
   a. Leak-detection equipment
   b. Self-contained breathing apparatus (Figure 6.17)
   c. Atmospheric monitoring devices

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[26] *See Chapter 7, "Laboratory Procedures" in SMALL WATER SYSTEM OPERATION AND MAINTENANCE, for proper procedures for collecting and analyzing samples for chlorine residuals and coliform tests.*

[27] *Amperometric Titration (am-PURR-o-MET-rick). A means of measuring concentrations of certain substances in water (such as strong oxidizers) based on the electric current that flows during a chemical reaction.*

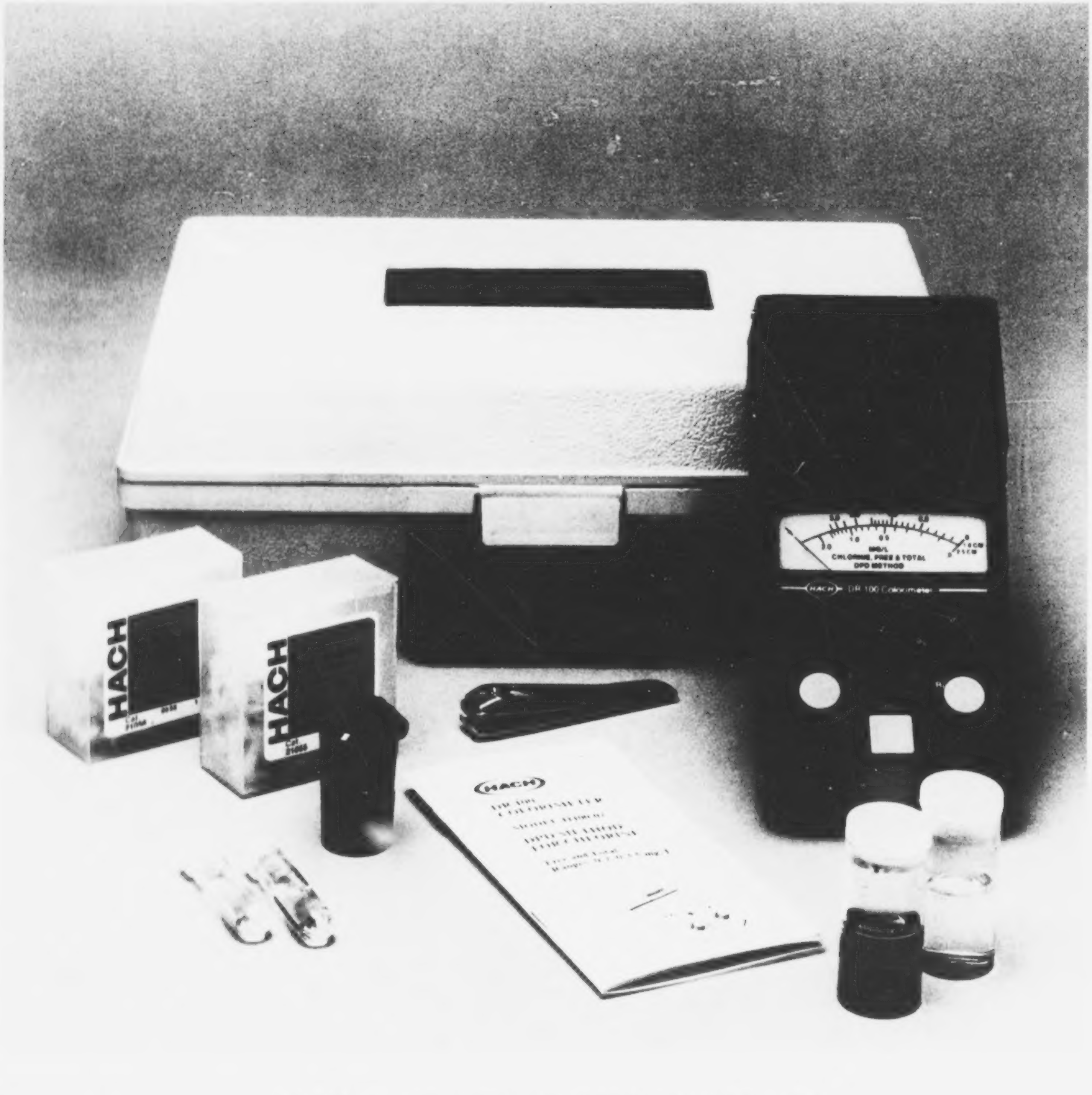
HACH
HACH
MG/L
CHLORINE, FREE & TOTAL
DPD METHOD
HACH DR 100 Colorimeter
HACH

Fig. 6.18 Direct reading colorimeter for free chlorine residuals
(Permission of the Hach Company)

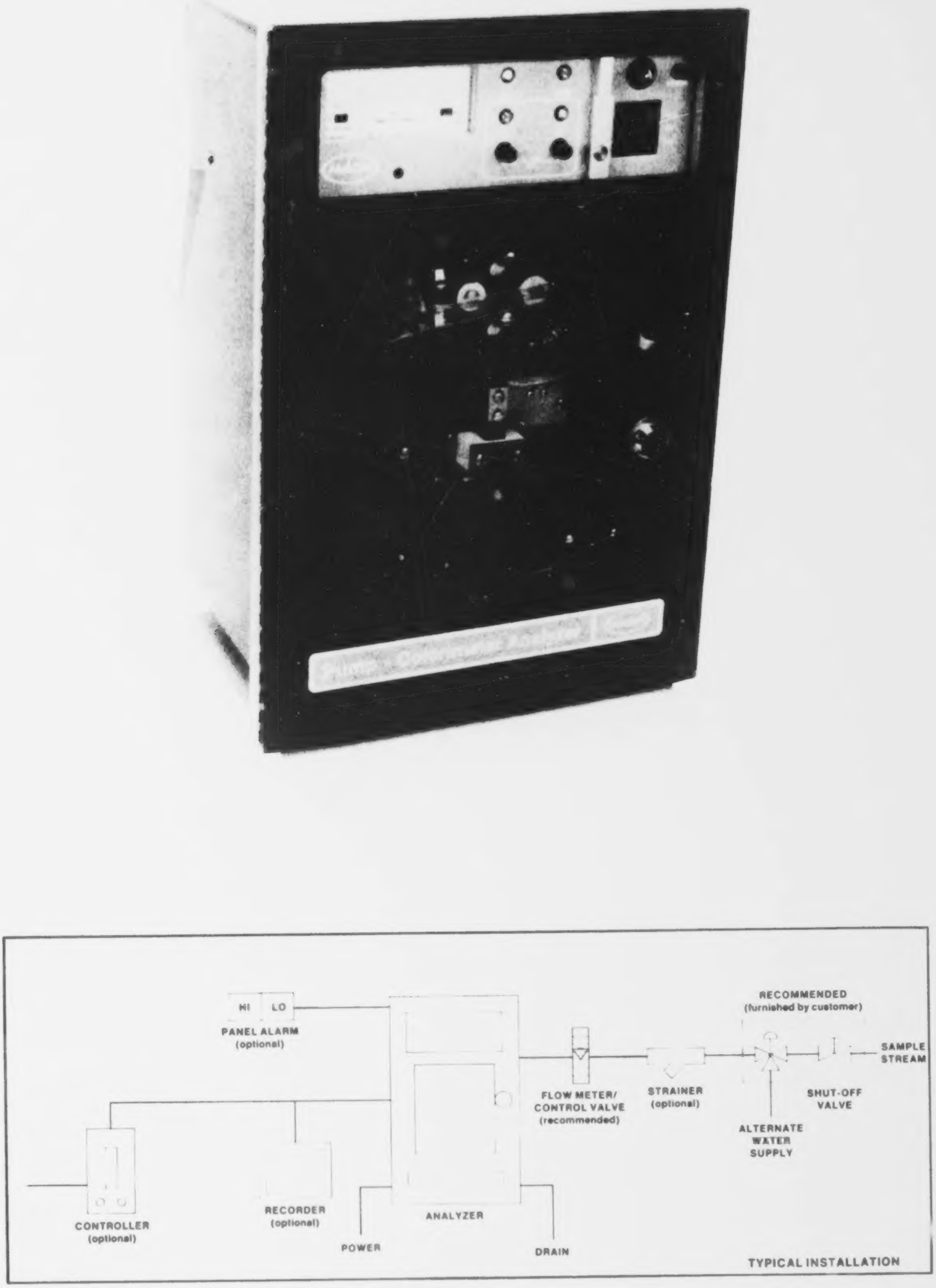
HI
LO
PANEL ALARM (optional)
RECOMMENDED (furnished by customer)
SAMPLE STREAM
FLOW METER/ CONTROL VALVE (recommended)
STRAINER (optional)
SHUT-OFF VALVE
ALTERNATE WATER SUPPLY
CONTROLLER (optional)
RECORDER (optional)
ANALYZER
POWER
DRAIN
TYPICAL INSTALLATION

Fig. 6.19 Continuous on-line free chlorine residual analyzer

(Permission of the Hach Company)

4. Establishment of emergency procedures for chlorine leaks and first aid.
5. Establishment of a maintenance and calibration program for safety devices and equipment.
6. Provide police and fire departments with tours of facilities to locate hazardous areas and provide chlorine safety information.

All persons handling chlorine should be thoroughly aware of its hazardous properties. Personnel should know the location and use of the various pieces of protective equipment and be instructed in safety procedures. In addition, an emergency procedure should be established and each individual should be instructed how to follow the procedures. An emergency checklist also should be developed and available. For additional information on this topic, see the Chlorine Institute's *CHLORINE MANUAL*, 4th Edition.[28] Also see Chapter 7, "Safety."

6.60 Chlorine Hazards

Chlorine is a gas, heavier than air, extremely toxic and corrosive in moist atmospheres. Dry chlorine gas can be safely handled in steel containers and piping, but with moisture must be handled in corrosion-resisting materials such as silver, glass, teflon, and certain other plastics. Chlorine gas at container pressure should never be piped in silver, glass, teflon, or any other material that cannot handle the pressure. Even in dry atmospheres chlorine combines with the moisture in the mucous membranes of the nose and throat, and with the fluids in the eyes and lungs; a very small percentage in the air can be very irritating and can cause severe coughing. Heavy exposure can be fatal (see Table 6.8).

WARNING

WHEN ENTERING A ROOM THAT MAY CONTAIN CHLORINE GAS, OPEN THE DOOR SLIGHTLY AND CHECK FOR THE SMELL OF CHLORINE. **NEVER** GO INTO A ROOM CONTAINING CHLORINE GAS WITH HARMFUL CONCENTRATIONS IN THE AIR WITHOUT A SELF-CONTAINED AIR SUPPLY, PROTECTIVE CLOTHING AND HELP STANDING BY. HELP MAY BE OBTAINED FROM YOUR CHLORINE SUPPLIER AND YOUR LOCAL FIRE DEPARTMENT.

Most people can usually detect concentrations of chlorine gas above 0.3 ppm and you should not be exposed to concentrations greater than 1 ppm. However, chlorine gas can deaden your sense of smell and cause a false sense of security. NEVER rely on your sense of smell to protect you from chlorine because YOUR sense of smell might not be able to detect harmful levels of chlorine.

6.61 Why Chlorine Must Be Handled With Care

You must always remember that chlorine is a hazardous chemical and must be handled with respect. Concentrations of chlorine gas in excess of 1000 ppm may be fatal after a few breaths.

Because the characteristic sharp odor of chlorine can be noticeable even when the amount of chlorine in the air is small, it is possible to get out of the gas area before serious harm is suffered. This feature of chlorine gas helps reduce potential operator exposure as compared with other hazardous gases such as carbon monoxide, which is odorless and gives no warning of exposure, and hydrogen sulfide, which impairs your sense of smell in a short time.

Inhaling chlorine causes general restlessness, panic, severe irritation of the throat, sneezing, and production of much saliva. These symptoms are followed by coughing, retching and vomiting, and difficulty in breathing. Chlorine is particularly irritating to persons suffering from asthma and certain types of chronic bronchitis. Liquid chlorine causes severe irritation and blistering on contact with the skin. Regular exposure to chlorine can produce chronic effects such as permanent damage to lung tissue.

6.62 Protect Yourself From Chlorine

Every person working with chlorine should know the proper ways to handle it, should be trained in the use of self contained breathing apparatus (SCBA), and should know what to do in case of emergencies. Wear a SCBA which protects your face, eyes and nose. The clothing of persons exposed to chlorine will be saturated with chlorine which will irritate the skin if exposed to moisture or sweat. These people should not enter confined spaces before their clothing is purged of chlorine (stand out in the open air for awhile). This is particularly applicable to police and fire department personnel who leave the scene of a chlorine leak and ride back to their stations in closed vehicles. Suitable protective clothing for working in an atmosphere containing chlorine include disposable rainsuits with hoods to protect your body, head and limbs and rubber boots.

CANISTER TYPE **'GAS MASKS'** ARE USUALLY **INADEQUATE** AND **INEFFECTIVE** IN SITUATIONS WHERE CHLORINE LEAKS OCCUR AND ARE THEREFORE NOT RECOMMENDED FOR USE UNDER ANY CIRCUMSTANCES. **SELF-CONTAINED AIR OR OXYGEN SUPPLY TYPE BREATHING APPARATUS ARE RECOMMENDED.** Operators serving on "emergency chlorine teams" must be carefully selected and receive regular approved training. They must be provided the proper equipment which receives regular maintenance and is ready for use at all time.

TABLE 6.8 PHYSIOLOGICAL RESPONSE TO CONCENTRATIONS OF CHLORINE GAS[a]

Effect	Parts of Chlorine Gas Per Million Parts of Air by Volume (ppm)
Slight symptoms after several hours' exposure	1[b]
Detectable odor	0.3 to 3.5
Noxiousness	5
Throat irritation	15
Coughing	30
Death after a few deep breaths	1000

[a] Adapted from data in U.S. Bureau of Mines TECHNICAL PAPER 248 (1955).

[b] OSHA regulations specify that exposure to chlorine shall at NO time exceed 1 ppm.

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[28] *Write to: The Chlorine Institute, Inc., 342 Madison Avenue, New York, New York 10017. Price $5.00.*

Self-contained air supply and demand-breathing equipment must fit properly and be used properly. Pressure demand and rebreather kits may be safer. Pressure demand units use more air from the air bottle which reduces the time a person may work on a leak.

Before entering an area with a chlorine leak, wear protective clothing. Gloves and a rubber suit will prevent chlorine from contacting the sweat on your body and forming hydrochloric acid. Rubber suits are very cumbersome, but should be worn when the weather it hot and humid and the chlorine concentration is high. Otherwise, use your own judgment regarding whether or not to wear protective clothing.

The best protection that one can have when dealing with chlorine is to respect it. Each individual should practice rules of safe handling and good PREVENTIVE MAINTENANCE.

PREVENTION IS THE BEST EMERGENCY TOOL YOU HAVE.

PLAN AHEAD.

1. Have your fire department tour the area so that they know where the facilities are located. Give them a clearly marked map indicating the location of the chlorine storage area, chlorinators, and gas masks.
2. Have emergency drills using chlorine gas masks and chlorine repair kits.
3. Have a supply of ammonia available to detect chlorine leaks.
4. Write emergency procedures.

   Prepare a CHLORINE EMERGENCY LIST of names or companies and phone numbers of persons to call during an emergency. This list should include:

   a. Fire department,
   b. Chlorine emergency personnel, and
   c. Chlorine supplier.
5. Follow established procedures during all emergencies.
   a. Never work alone during chlorine emergencies.
   b. Obtain help immediately and quickly repair the problem. PROBLEMS DO NOT GET BETTER.
   c. Only authorized and properly trained persons with adequate equipment should be allowed in the danger area to correct the problem.
   d. If you are caught in a chlorine atmosphere without a gas mask, shallow breathing is safer than breathing deeply. Recovery depends upon the duration and amount of chlorine inhaled, so it is important to keep that amount as small as possible.
   e. If you discover a chlorine leak, leave the area immediately unless it is a very minor leak. Small leaks can be found by using a rag soaked with ammonia. A white gas will form near the leak so it can be located and corrected.
   f. Use approved respiratory protection and water disposable clothing when repairing a chlorine leak.
   g. Notify your police department that you need help if it becomes necessary to stop traffic on roads and to evacuate persons in the vicinity of the chlorine leak.
6. Develop emergency evacuation procedures for use during a serious chlorine leak. Coordinate these procedures with your police department and other officials.
7. Post emergency procedures in all operating areas.
8. Inspect equipment and routinely make any necessary repairs.
9. At least twice weekly, inspect area where chlorine is stored and where chlorinators are located. Remove all obstructions from the area.
10. Schedule routine maintenance on ALL chlorine equipment at least once every six months or more frequently.
11. Have health appraisal for employees on chlorine emergency duty. No one with heart and respiratory problems should be allowed on emergency teams.

REMEMBER:

Small amounts of chlorine cause large problems. Leaks never get better.

6.63 First Aid Measures

MILD CASES

Whenever you have a mild case of chlorine exposure (which does happen from time to time around chlorination equipment), you should first leave the contaminated area. Move slowly, breathe lightly without exertion, remain calm, keep warm and resist coughing. Notify other operators and have them repair the leak immediately.

If clothing has been contaminated, remove as soon as possible. Otherwise the clothing will continue to give off chlorine gas which will irritate the body even after leaving the contaminated area. Immediately wash off area affected by chlorine. Shower and put on clean clothes.

If victim has slight throat irritation, immediate relief can be accomplished by drinking milk. Drinking spirits of peppermint also will help reduce throat irritation. See a physician.

EXTREME CASES

1. Follow established emergency procedures.
2. Always use proper safety equipment. Do not enter area without a self-contained breathing apparatus.
3. Remove patient from affected area immediately.
4. First aid:
   a. Remove contaminated clothes to prevent clothing giving off chlorine gas which will irritate the body.
   b. Keep patient warm and cover with blankets if necessary.
   c. Place patient in a comfortable position on back.
   d. EYES!

      If even a small amount of chlorine gets into the eyes, they should be flushed with water. The flushing should continue so that all traces of chlorine are flushed from the eyes.
5. See a physician.

6.64 Hypochlorite Safety

Hypochlorite does not present the hazards that gaseous chlorine does and therefore is safer to handle. When spills occur, wash with large volumes of water. The solution is messy to handle. Hypochlorite causes damage to your eyes and skin upon contact. Immediately wash affected areas thoroughly with water. Consult a physician if the area appears burned. Hypochlorite solutions are very corrosive. Hypochlorite compounds are non-flammable; however, they can cause fires when they come in contact with organics or other easily oxidizable substances.

6.65 Chlorine Dioxide Safety

Chlorine dioxide is generated in much the same manner as chlorine and should be handled with the same care. Of special concern is the use of sodium chlorite to generate chlorine dioxide. Sodium chlorite is very combustible around organic compounds. Whenever spills occur, sodium chlorite must be neutralized with anhydrous sodium sulfite. Combustible materials (including gloves) should not be worn when handling sodium chlorite. If sodium chlorite comes in contact with clothing, the clothes should be removed immediately and soaked in water to remove all traces of sodium chlorite or the clothes should be burned immediately.

6.66 Operator Safety Training

Training is a concern to everyone, especially when your safety and perhaps your life is concerned. Every utility agency should have an operator chlorine safety training program which introduces new operators to the program and updates previously trained operators. As soon as a training session ends, obsolescence begins. People will forget what they have learned if they don't use and practice their knowledge and skills. Operator turnover can dilute a well-trained staff. New equipment and also new techniques and procedures can dilute the readiness of trained operators. An on-going training program can consist of a monthly luncheon seminar, a monthly safety bulletin that is to be read by every operator, and outside speakers can be brought in to reinforce and refresh specific elements of a safety training program.

The American Water Works Association (AWWA) is an excellent source of training materials for safety programs. Films are available from AWWA for rental fees of around $15.00. Typical films include "A Demonstration of the A, B and C Emergency Kits." This film illustrates the application of the Chlorine Institute's A, B and C emergency repair devices. "Safe Handling of Chlorine" is a film about procedures for handling chlorine cylinders, ton containers, tank cars and barges. Also discussed are appropriate materials for construction, pumping chlorine, checking storage tanks, operating vaporizers, repacking valves, and training operators how to safely handle chlorine. To obtain these and other films, write or call AWWA, Library, 6666 West Quincy Avenue, Denver, Colorado 80235; phone 303-794-7711.

6.67 CHEMTREC (800-424-9300)

Safely handling chemicals used in daily water treatment is an operator's responsibility. However, if the situation ever gets out of hand, there are emergency teams that will respond with help anywhere there is an emergency. If an emergency does develop in your plant and you need assistance, call CHEMTREC (Chemical Transportation Emergency Center) for assistance. CHEMTREC will provide immediate advice for those at the scene of an emergency and then quickly alert experts whose products are involved for more detailed assistance and appropriate follow-up.

CHEMTREC'S EMERGENCY TOLL-FREE PHONE NUMBER IS 800-424-9300.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 337.

6.6A What properties make chlorine gas so hazardous?

6.6B What type of breathing apparatus is recommended when repairing a chlorine leak?

6.6C What first aid measures should be taken if a person comes in contact with chlorine gas?

6.6D What would you do if hypochlorite came in contact with your hand?

6.7 CHLORINATION ARITHMETIC

All calculations in this section can be performed by addition, subtraction, multiplication and division on a pocket electronic calculator.

FORMULAS

There are two approaches to calculating chlorine doses in milligrams per liter. They are both the same, but have a slightly different form. From the basic equation on page 512,

Chlorine, lbs = (Volume, M Gal)(Dose, mg/*L*)(8.34 lbs/gal),

we can rearrange the equation and solve for the dose in milligrams per liter.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine, lbs}}{(\text{Volume, M Gal})(8.34\ \text{lbs/day})}$$

If the basic equation is expressed as a chemical feeder setting in pounds per day, then the flow would be in million gallons per day (MGD).

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine, lbs/day}}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

Both of the above equations are also in terms of pounds or pounds per day of chlorine per million pounds or million pounds per day of water.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine, lbs/day}}{\text{Water, Million lbs/day}}$$

6.70 Disinfection of Facilities

6.700 Wells and Pumps

EXAMPLE 8

How many gallons of 5.25 percent sodium hypochlorite will be needed to disinfect a well with an 18-inch diameter casing and well screen? The well is 300 feet deep and there is 200 feet of water in the well. Use an initial chlorine dose of 100 mg/*L*.

Known		**Unknown**
Hypochlorite, %	= 5.25%	5.25% Hypochlorite, gal
Chlorine Dose, mg/*L*	= 100 mg/*L*	
Well Casing, in	= 18 in	
Well Depth, ft	= 300 ft	
Water Depth, ft	= 200 ft	

1. Find the volume of water in the well in gallons.

$$\text{Well Vol, Gal} = (0.785)(\text{Diameter, ft})^2(\text{Water Depth, ft})(7.48\text{ gal/cu ft})$$

$$= \frac{(0.785)(18\text{ in})^2(200\text{ ft})(7.48\text{ gal/cu ft})}{144\text{ sq in/sq ft}}$$

$$= 2642\text{ gal}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.002642\text{ M Gal})(100\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 2.2\text{ lbs chlorine}$$

3. Calculate the gallons of 5.25 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(2.2\text{ lbs})(100\%)}{(8.34\text{ lbs/gal})(5.25\%)}$$

$$= 5.0\text{ gallons}$$

Five gallons of 5.25 percent sodium hypochlorite should do the job.

6.701 Mains

EXAMPLE 9

A section of an old 8-inch water main has been replaced and a 350-foot section of pipe needs to be disinfected. An initial chlorine dose of 400 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution will be needed?

Known		Unknown
Diameter of Pipe, in	= 8 in	5.25% Hypochlorite, gallons
or 8 in/12 in/ft	= 0.67 ft	
Length of Pipe, ft	= 350 ft	
Chlorine Dose, mg/*L*	= 400 mg/*L*	
Hypochlorite, %	= 5.25%	

1. Calculate the volume of water in the pipe in gallons.

$$\text{Pipe Volume, gallons} = (0.785)(\text{Diameter, ft})^2(\text{Length, ft})(7.48\text{ gal/cu ft})$$

$$= (0.785)(0.67\text{ ft})^2(350\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 923\text{ gallons of water}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.000923\text{ M Gal})(400\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 3.08\text{ lbs/chlorine}$$

3. Calculate the gallons of 5.25 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(3.08\text{ lbs})(100\%)}{(8.34\text{ lbs/gal})(5.25\%)}$$

$$= 7.0\text{ gallons}$$

Seven gallons of 5.25 percent solution of sodium hypochlorite should do the job.

6.702 Tanks

EXAMPLE 10

An existing service storage reservoir has been taken out of service for inspection, maintenance and repairs. The reservoir needs to be disinfected before being placed back on line. The reservoir is 6 feet deep, 10 feet wide and 25 feet long. An initial chlorine dose of 100 mg/*L* is expected to maintain a chlorine residual of over 50 mg/*L* during the 24-hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution will be needed?

Known		Unknown
Tank Depth, ft	= 6 ft	5.25% Hypochlorite, gal
Tank Width, ft	= 10 ft	
Tank Length, ft	= 25 ft	
Chlorine Dose, mg/*L*	= 100 mg/*L*	
Hypochlorite, %	= 5.25%	

1. Calculate the volume of water in the tank in gallons.

$$\text{Tank Volume, gallons} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

$$= (25\text{ ft})(10\text{ ft})(6\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 11{,}220\text{ gallons}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Vol Water, M Gal})(\text{Chlorine Dose, mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.01122\text{ M Gal})(100\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 9.36\text{ lbs chlorine}$$

3. Calculate the gallons of 5.25 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(9.36\text{ lbs})(100\%)}{(8.34\text{ lbs/gal})(5.25\%)}$$

$$= 21.4\text{ gallons}$$

Twenty-two gallons of 5.25 percent sodium hypochlorite solution should do the job.

6.71 Disinfection of Water from Wells

6.710 Chlorine Dose

EXAMPLE 11

A chlorine demand test from a well water sample produced a result of 1.2 mg/*L*. The water supplier would like to maintain a chlorine residual of 0.2 mg/*L* throughout the system. What should be the chlorine dose in mg/*L* from either a chlorinator or hypochlorinator?

Known		Unknown
Chlorine Demand, mg/*L*	= 1.2 mg/*L*	Chlorine Dose, mg/*L*
Chlorine Residual, mg/*L*	= 0.2 mg/*L*	

Calculate the chlorine dose in mg/*L*.

$$\text{Chlorine Dose, mg}/L = \text{Chlorine Demand, mg}/L + \text{Chlorine Residual, mg}/L$$

$$= 1.2\text{ mg}/L + 0.2\text{ mg}/L$$

$$= 1.4\text{ mg}/L$$

NOTE: Be sure to check the chlorine residual regularly throughout the system. If the residual is low or there are coliforms present in the test results, then the residual should be increased.

6.711 Chlorinator

EXAMPLE 12

A deep-well turbine pump is connected to a hydropneumatic tank. Under normal operating heads, the pump delivers 500 GPM. If the desired chlorine dosage is 3.5 mg/*L*, what should be the setting on the rotameter for the chlorinator (lbs chlorine per 24 hours)?

Known		Unknown
Pump Flow, GPM	= 500 GPM	Rotameter Setting, lbs chlorine/24 hours
Chlorine Dose, mg/*L*	= 3.5 mg/*L*	

1. Convert pump flow to million gallons per day (MGD).

$$\text{Flow, MGD} = \frac{(500\text{ GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hrs/day})}{1{,}000{,}000}$$

$$= 0.72\text{ MGD}$$

2. Calculate the rotameter setting in pounds of chlorine per 24 hours.

$$\text{Rotameter Setting, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.72\text{ MGD})(3.5\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 21.0\text{ lbs chlorine/day}$$

$$= 21.0\text{ lbs chlorine/24 hours}$$

EXAMPLE 13

Using the results from EXAMPLE 12 (a chlorinator setting of 21 lbs per 24 hours), how many pounds of chlorine would be used in one month if the pump hour meter shows the pump operates an average of 20 hours per day? The chlorinator operates only when the pump operates. How many 150-pound cylinders will be needed per month?

Known		Unknown
Chlorinator Setting, lbs/day	= 21 lbs/day	1. Chlorine Used, lbs/mo
Pump Operation, hrs/day	= 20 hrs/day	2. Cylinders Needed, no/mo
Chlorine Cylinders, lbs/cyl	= 150 lbs/cyl	

1. Calculate the chlorine used in pounds per month.

$$\text{Chlorine Used, lbs/mo} = \frac{(\text{Cl Setting, lbs/day})(\text{Operation, hr/day})(30\text{ days/mo})}{24\text{ hrs/day}}$$

$$= \frac{(21\text{ lbs/day})(20\text{ hrs/day})(30\text{ days/mo})}{24\text{ hrs/day}}$$

$$= 525\text{ lbs/mo}$$

2. Determine the number of 150-pound cylinders used per month.

$$\text{Cylinders Needed, no/mo} = \frac{\text{Chlorine Used, lbs/mo}}{150\text{ lbs Chlorine/cylinder}}$$

$$= \frac{525\text{ lbs Cl/mo}}{150\text{ lbs Cl/cylinder}}$$

$$= 3.5\text{ cylinders/month}$$

EXAMPLE 14

A deep-well turbine pump delivers 400 GPM throughout a 24-hour period. The weight of chlorine in a 150-pound cylinder was 123 pounds at the start of the time period and 109 pounds at the end of the 24 hours. What was the chlorine dose rate in mg/*L*?

Known		Unknown
Pump Flow, GPM	= 400 GPM	Chlorine dose, mg/*L*
Time Period, hrs	= 24 hrs	
Chlorine Wt at Start, lbs	= 123 lbs	
Chlorine Wt at End, lbs	= 109 lbs	

1. Convert flow of 400 GPM to MGD.

$$\text{Flow, MGD} = \frac{(400\text{ gal/min})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}$$

$$= 0.576\text{ MGD}$$

2. Calculate the chlorine dose rate in mg/*L*.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine Used, lbs/day}}{(\text{Flow, MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{(123\text{ lbs} - 109\text{ lbs})/1\text{ day}}{(0.576\text{ MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{14\text{ lbs chlorine/day}}{(0.576\text{ MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{2.9\text{ lbs Chlorine}}{1\text{ M lbs Water}}$$

$$= 2.9\text{ mg}/L$$

6.712 Hypochlorinator

EXAMPLE 15

Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 50 gallons per day (GPD) and uses a 3 percent available hypochlorite solution, what is the chlorine dose rate in mg/*L* if the pump delivers 350 GPM?

Known		Unknown
Hypochlorinator, GPD	= 50 GPD	Chlorine Dose, mg/*L*
Hypochlorite, %	= 3%	
Pump, GPM	= 350 GPM	

1. Convert the pumping rate to MGD.

$$\text{Pumping Rate, MGD} = \frac{(350\text{ GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}$$

$$= 0.50\text{ MGD}$$

2. Calculate the chlorine dose rate in pounds per day.

$$\text{Chlorine Dose, lbs/day} = \frac{(\text{Flow, gal/day})(\text{Hypochlorite, \%})(8.34\ \text{lbs/gal})}{100\%}$$

$$= \frac{(50\ \text{gal/day})(3\%)(8.34\ \text{lbs/gal})}{100\%}$$

$$= 12.5\ \text{lbs/day}$$

3. Calculate the chlorine dose in mg/*L*.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine Dose, lbs/day}}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

$$= \frac{12.5\ \text{lbs chlorine/day}}{(0.50\ \text{M gal/day})(8.34\ \text{lbs/gal})}$$

$$= 3\ \text{lbs chlorine/M lbs water}$$

$$= 3\ \text{mg}/L$$

EXAMPLE 16

Water pumped from a well is disinfected by a hypochlorinator. During a one-week time period, the water meter indicated that 1,098,000 gallons of water were pumped. A 2.0 percent sodium hypochlorite solution is stored in a 2.5-foot diameter plastic tank. During this one-week time period, the level of hypochlorite in the tank dropped 18 inches (1.50 ft). What was the chlorine dose in mg/*L*?

Known		Unknown
Water Treated, M Gal	= 1.098 M Gal	Chlorine Dose, mg/*L*
Hypochlorite, %	= 2.0%	
Hypochlorite Tank D, ft	= 2.5 ft	
Hypochlorite Used, ft	= 1.5 ft	

1. Calculate the pounds of water disinfected.

$$\text{Water, lbs} = (\text{Water Treated, M Gal})(8.34\ \text{lbs/gal})$$

$$= (1.098\ \text{M Gal})(8.34\ \text{lbs/gal})$$

$$= 9.16\ \text{M lbs water}$$

2. Calculate the volume of hypochlorite solution used in gallons.

$$\text{Hypochlorite, gal} = (0.785)(\text{Diameter, ft})^2(\text{Drop, ft})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(2.5\ \text{ft})^2(1.5\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 55.0\ \text{gallons}$$

3. Determine the pounds of chlorine used to treat the water.

$$\text{Chlorine, lbs} = (\text{Hypochlorite, gal})\left(\frac{\text{Hypochlorite, \%}}{100\%}\right)(8.34\ \text{lbs/gal})$$

$$= (55.0\ \text{gal})\left(\frac{2.0\%}{100\%}\right)(8.34\ \text{lbs/gal})$$

$$= 9.17\ \text{lbs chlorine}$$

4. Calculate the chlorine dose in mg/*L*.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorine Used, lbs}}{\text{Water Treated, Million lbs}}$$

$$= \frac{9.17\ \text{lbs Chlorine}}{9.16\ \text{M lbs Water}}$$

$$= \frac{1.0\ \text{lbs Chlorine}}{1\ \text{M lbs water}}$$

$$= 1.0\ \text{mg}/L$$

EXAMPLE 17

Estimate the required concentration of a hypochlorite solution (%), if a pump delivers 600 GPM from a well. The hypochlorinator can deliver a maximum of 120 GPD and the desired chlorine dose is 1.8 mg/*L*.

Known		Unknown
Pump Flow, GPM	= 600 GPM	Hyporchlorite Strength, %
Hypo Cl Flow, GPD	= 120 GPD	
Chlorine Dose, mg/*L*	= 1.8 mg/*L*	

1. Calculate the flow of water treated in million gallons per day.

$$\text{Water Treated, M gal/day} = \frac{(600\ \text{GPM})(1\ \text{Million})(60\ \text{min/hr})(24\ \text{hrs/day})}{1{,}000{,}000}$$

$$= 0.864\ \text{MGD}$$

2. Determine the pounds of chlorine required per day.

$$\text{Chlorine Required, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)8.34\ \text{lbs/gal})$$

$$= (0.864\ \text{MGD})(1.8\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 13.0\ \text{lbs chlorine/day}$$

3. Calculate the hypochlorite solution strength as a percent.

$$\text{Hypochlorite Strength, \%} = \frac{(\text{Chlorine Required, lbs/day})(100\%)}{(\text{Hypochlorinator Flow, GPD})(8.34\ \text{lbs/gal})}$$

$$= \frac{(13.0\ \text{lbs/day})(100\%)}{(120\ \text{GPD})(8.34\ \text{lbs/gal})}$$

$$= 1.3\%$$

EXAMPLE 18

A hypochlorite solution for a hypochlorinator is being prepared in a 55-gallon drum. If 10 gallons of 5 percent hypochlorite is added to the drum, how much water should be added to the drum to produce a 1.3 percent hypochlorite solution?

Known		Unknown
Drum Capacity, gal	= 55 gal	Water Added, gal
Hypochlorite, gal	= 10 gal	
Hypochlorite, %	= 5%	
Desired Hypo, %	= 1.3%	

Calculated the volume of water to be added in gallons.

$$\text{Desired Hypo, \%} = \frac{(\text{Hypo, gal})(\text{Hypo, \%})}{\text{Hypo, gal} + \text{Water Added, gal}}$$

Rearrange the terms in the equation.

$$(\text{Desired Hypo, \%})(\text{Hypo, gal} + \text{Water Added, gal}) = (\text{Hypo, gal})(\text{Hypo, \%})$$

$$(\text{Desired Hypo, \%})(\text{Hypo, gal}) + (\text{Desired Hypo, \%})(\text{Water Added, gal}) = (\text{Hypo, gal})(\text{Hypo, \%})$$

$$(\text{Desired Hypo, \%})(\text{Water Added, gal}) = (\text{Hypo, gal})(\text{Hypo, \%}) - (\text{Desired Hypo, \%})(\text{Hypo, gal})$$

$$\text{Water Added, gal} = \frac{(\text{Hypo, gal})(\text{Hypo, \%}) - (\text{Desired Hypo, \%})(\text{Hypo, gal})}{\text{Desired Hypo, \%}}$$

$$= \frac{(10\ \text{gal})(5\%) - (1.3\%)(10\ \text{gal})}{1.3\%}$$

$$= \frac{50 - 13}{1.3}$$

$$= 28.5\ \text{gallons of water}$$

Add 28.5 gallons of water to the 10 gallons of 5 percent hypochlorite in the drum.

PLUS EQUALS
% MINUS

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 337.

6.7A A section of 12-inch water main has been repaired and a 400-ft section of pipe needs to be disinfected. An initial chlorine dose of 450 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many gallons of 5 percent sodium hypochlorite solution will be needed?

6.7B Estimate the chlorine demand of a water that is dosed at 2.0 mg/*L*. The chlorine residual is 0.2 mg/*L* after a 30-minute contact period.

6.7C What should be the setting on a chlorinator (lbs chlorine per 24 hours) if a pump usually delivers 600 GPM and the desired chlorine dosage is 4.0 mg/*L*?

6.7D Water from a well is being disinfected by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 60 gallons per day (GPD) and uses a 2 percent available chlorine solution, what is the chlorine dose rate in mg/*L*? The pump delivers 400 GPM.

6.8 ARITHMETIC ASSIGNMENT

Turn to the Appendix at the back of this manual and read Section A.9, "Steps in Solving Problems." Also work the example problems and check the arithmetic using your calculator.

In Section A.13, "Typical Water Supply System Operation Problems," read and work the problems in Section A.134, "Disinfection."

6.9 ADDITIONAL READING

1. *NEW YORK MANUAL*, Chapter 10, "Chlorination."
2. *TEXAS MANUAL*, Chapter 10, "Disinfection of Water."
3. *CHLORINE MANUAL*, The Chlorine Institute, Inc., 342 Madison Avenue, New York, N.Y. 10173. Price, $5.00.
4. *CHLORINE MANUAL*, Chlor-Alkali Business Unit, Chemical Division, PPG Industries Inc., One Gateway Center, Pittsburgh, Pennsylvania 15222
5. *CHLORINE SAFE HANDLING*, Chlor-Alkali Business Unit, Chemical Division, PPG Industries Inc., One Gateway Center, Pittsburgh, Pennsylvania 15222.
6. *BASIC GAS CHLORINATION WORKSHOP MANUAL*. Obtain from Training and Certification Section, Ministry of the Environment, 135 St. Clair Avenue West, Toronto 7, Ontario, M4V 1P5 CANADA.
7. *AWWA STANDARD FOR DISINFECTING WATER MAINS*. C601-81. Obtain from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 43601. Price to members, $7.00; nonmembers, $8.50.
8. *AWWA STANDARD FOR DISINFECTING WATER STORAGE FACILITIES*, D105-80. Obtain from Computer Services, AWWA, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 44105. Price to members, $5.00; nonmembers, $6.50.

6.10 ACKNOWLEDGEMENT

Mr. Malcolm P. Dalton, General Manager, and Mr. James F. Brace, Staff Assistant, Navajo Tribal Utility Authority, provided many helpful contributions to all aspects of safety throughout this entire manual.

End of Lesson 2 of 2 Lessons
on
DISINFECTION

DISCUSSION AND REVIEW QUESTIONS

Chapter 6. DISINFECTION

(Lesson 2 of 2 Lessons)

Write the answers to these questions in your notebook before continuing with the Objective Test on page 338. The problem numbering continues from Lesson 1.

8. What procedures would you follow to safely handle chlorine cylinders?
9. What precautions would you take when shutting down a hypochlorinator to make repairs for a short duration?
10. How would you determine whether or not the chlorine feed rate of a chlorinator needs adjustment?
11. How would you determine the desired strength of a hypochlorite solution in the solution tank for effective operation of a hypochlorinator?
12. Why is safety equipment needed when repairing a chlorine leak?
13. How would you detect a chlorine leak?
14. What would you do if you could not repair a broken chlorinator quickly?
15. Why should clothing be removed from a person who has been in an area contaminated with liquid or gaseous chlorine?

SUGGESTED ANSWERS

CHAPTER 6. DISINFECTION

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 292.

6.0A Pathogenic organisms are disease-producing organisms.

6.0B Disinfection is the selective destruction of pathogenic organisms.

6.0C The U.S. Environmental Protection Agency establishes drinking water standards.

6.0D MCL stands for **M**aximum **C**ontaminant **L**evel.

Answers to questions on page 295.

6.1A Relatively cold water requires longer disinfection time or greater quantities of disinfectants.

6.1B Most disinfectants are more effective in water with a pH around 7.0 than in water above a pH of 8.0.

6.1C The greater the number and type of microorganisms present, the greater may be the adverse influence on the effectiveness of the disinfectant.

Answers to questions on page 296.

6.2A Physical agents that have been used for disinfection other than chlorine include (1) ultraviolet rays, (2) heat and (3) ultra sonic waves.

6.2B Chemical agents that have been used for disinfection other than chlorine include (1) iodine, (2) bromine, (3) bases (sodium hydroxide and lime), and (4) ozone.

6.2C A major limitation to the use of ozone is the inability of ozone to provide a residual in the distribution system.

Answers to questions on page 297.

6.2D Hydrogen sulfide and ammonia are two inorganic reducing chemicals that react rapidly with chlorine.

6.2E
$$\text{Chlorine Demand, mg}/L = \text{Chlorine Dose, mg}/L - \text{Chlorine Residual, mg}/L$$

6.2F
$$\text{Chlorine Dose, mg}/L = \text{Chlorine Demand, mg}/L + \text{Chlorine Residual, mg}/L$$

Answers to questions on page 299.

6.2G The higher the pH level, the greater the percent of OCl^-.

6.2H Chlorine gas tends to lower the pH while hypochlorite tends to increase the pH.

Answers to questions on page 304.

6.3A When disinfecting a well, the well, pump, screen and aquifer around the well all should be disinfected because they all could have been contaminated during construction and are potential sources of contamination.

6.3B The chlorine solution should be applied to the well by injecting the chlorine down the pump down column pipe rather than injected through the vent pipe.

6.3C A well has been successfully disinfected if the results of a bacteriological analysis for total coliforms are negative (no coliforms.)

Answers to questions on page 309.

6.3D Water mains can be kept clean during construction and repair by keeping material such as dirt, construction materials, animals, rodents and dirty water out of the mains. Inspecting the pipes when laid, keeping trenches dry and installing watertight plugs all help to keep pipes clean.

6.3E Areas in a water main that require an extra effort for successful disinfection include fittings, valves and air pockets where chlorine might not come in contact with the surface.

6.3F Three forms of chlorine used for disinfection include:

1. Chlorine gas (liquid chlorine in cylinders),
2. Calcium hypochlorite, and
3. Sodium hypochlorite.

6.3G Water used for disinfection that has a high chlorine residual may be disposed of in sanitary sewers, storm sewers, or on land, but should not be disposed of in a manner that will cause an adverse impact on the enviroment.

6.3H Before a water main is disinfected, the main should be flushed for at least 30 minutes with a flushing velocity of 2.5 ft/sec.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 315.

6.4A The two major types of chlorine feeders are (1) hypochlorinators and (2) chlorinators.

6.4B Chlorine booster pumps are needed on most well applications to overcome the higher water pump discharge pressures.

9.4C The maximum rate of chlorine removal from a 150-pound cylinder is 40 pounds of chlorine per day.

Answers to questions on page 323.

6.4D The chemical feed of a hypochlorinator is adjusted until an adquate chlorine residual exists throughout the system and coliform test results are negative.

6.4E The level of the hypochlorite solution tank should be read at the same time every day.

6.4F The strength of the hypochlorite solution in the solution tank is adjusted so that the frequency of the strokes or pulses from the solution feed pump will be close together. This insures that chlorine will be fed continuously to the water treated.

6.4G Maintenance usually required of hypochlorinators includes oil changes and lubrication.

Answers to questions on page 326.

6.4H Before attempting to locate and repair a chlorine gas leak, you should have protective clothing (gloves and *rubber suit) and self-contained pressure-demand air supply.*

6.4I A chlorine leak can be detected by holding an ammonia soaked rag near suspected leaks. A white cloud will reveal the location of the leak.

6.4J If a chlorinator cannot be repaired quickly, shut off the water supply so that unchlorinated or contaminated water will not be delivered to consumers. Also shut off chlorine supply so chlorine line can be purged.

6.4K The two most common water quality tests run on samples of water from a water supply system are (1) chlorine residual and (2) coliform tests.

Answers to questions on page 326.

6.5A Chlorine residual is measured in treated water by the use of (1) amperometric titration and (2) DPD colorimetric method.

6.5B Residual chlorine measurements of treated water should be taken three times per day on small systems and once every two hours on large systems.

Answers to questions on page 331.

6.6A Chlorine gas is extremely toxic and corrosive in most atmospheres.

6.6B A properly fitting self-contained air or oxygen supply type of breathing apparatus, pressure demand, or a rebreather kit is recommended when repairing a chlorine leak.

6.6C First aid measures depend on the severity of the contact. Remove the victim from the gas area and keep the victim warm and quiet. Call a doctor and the fire department immediately. Keep the patient breathing.

6.6D Whenever hypochlorite comes in contact with your hand, immediately wash the hypochlorite off and thoroughly wash your hand. Consult a physician if the area appears burned.

Answers to questions on page 335.

6.7A

Known		**Unknown**
Diameter of Pipe, in	= 12 in	Hypochlorite, gallons
or ft	= 1.0 ft	
Length of Pipe, ft	= 400 ft	
Chlorine Dose, mg/*L*	= 450 mg/*L*	
Hypochlorite, %	= 5%	

1. Calculate the volume of water in the pipe in gallons.

$$\begin{aligned}\text{Pipe Volume, gallons} &= (0.785)(\text{Diameter, ft})^2(\text{Length, ft})(7.48\text{ gal/cu ft})\\ &= (0.785)(1.0\text{ ft})^2(400\text{ ft})(7.48\text{ gal/cu ft})\\ &= 2349\text{ gallons}\end{aligned}$$

2. Determine the pounds of chlorine needed.

$$\begin{aligned}\text{Chlorine, lbs} &= (\text{Vol Water, M Gal})(\text{Chlorine Dose, mg}/L)(8.34\text{ lbs/gal})\\ &= (0.002349\text{ M Gal})(450\text{ mg}/L)(8.34\text{ lbs/gal})\\ &= 8.82\text{ lbs chlorine}\end{aligned}$$

3. Calculate the gallons of 5 percent sodium hypochlorite solution needed.

$$\begin{aligned}\text{Sodium Hypochlorite Solution, gallons} &= \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}\\ &= \frac{(8.82\text{ lbs Chlorine})(100\%)}{(8.34\text{ lbs/gal})(5\%)}\\ &= 21.2\text{ gallons}\end{aligned}$$

A little over 21 gallons of hypochlorite should do the job.

6.7B

Known		**Unknown**
Chlorine Dose, mg/*L*	= 2.0 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual, mg/*L*	= 0.2 mg/*L*	

Calculate the chlorine demand in mg/*L*.

$$\begin{aligned}\text{Chlorine Demand, mg}/L &= \text{Chlorine Dose, mg}/L - \text{Chlorine Residual, mg}/L\\ &= 2.0\text{ mg}/L - 0.2\text{ mg}/L\\ &= 1.8\text{ mg}/L\end{aligned}$$

6.7C

Known		**Unknown**
Pump Flow, GPM	= 600 GPM	Chlorinator Setting, lbs Chlorine/24 hrs
Chlorine Dose, mg/*L*	= 4.0 mg/*L*	

1. Convert pump flow to million gallons per day (MGD).

$$\begin{aligned}\text{Flow, MGD} &= \frac{(600\text{ GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= 0.864\text{ MGD}\end{aligned}$$

2. Calculate the chlorinator setting in pounds of chlorine per 24 hours.

$$\begin{aligned}\text{Chlorinator Setting, lbs/24 hrs} &= (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})\\ &= (0.864\text{ MGD})(4.0\text{ mg}/L)(8.34\text{ lbs/gal})\\ &= 28.8\text{ lbs chlorine/day}\\ &= 28.8\text{ lbs chlorine/24 hours}\end{aligned}$$

6.7D

Known		**Unknown**
Hypochlorinator, GPD	= 60 GPD	Chlorine Dose, mg/*L*
Hypochlorite, %	= 2%	
Pump, GPM	= 400 GPM	

1. Convert the pumping rate to MGD.

$$\begin{aligned}\text{Pumping Rate, MGD} &= \frac{(400\text{ GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= 0.58\text{ MGD}\end{aligned}$$

2. Calculate the chlorine dose rate in pounds per day.

$$\begin{aligned}\text{Chlorine Dose, lbs/day} &= \frac{(\text{Flow, gal/day})(\text{Hypochlorite, }\%)(8.34\text{ lbs/gal})}{100\%}\\ &= \frac{(60\text{ GPD})(2\%)(8.34\text{ lbs/gal})}{100\%}\\ &= 10.0\text{ lbs chlorine/day}\end{aligned}$$

3. Calculate the chlorine dose in mg/*L*.

$$\begin{aligned}\text{Chlorine Dose, mg}/L &= \frac{\text{Chlorine Dose, lbs/day}}{(\text{Flow, MGD})(8.34\text{ lbs/gal})}\\ &= \frac{10.0\text{ lbs chlorine/day}}{(0.58\text{ MGD})(8.34\text{ lbs/gal})}\\ &= 2.1\text{ lbs chlorine/M lbs water}\\ &= 2.1\text{ mg}/L\end{aligned}$$

OBJECTIVE TEST

Chapter 6. DISINFECTION

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True — False

1. Disinfection is intended to kill all pathogenic organisms.
   1. True
   2. False
2. Chlorination is an effective means of sterilizing water.
   1. True
   2. False
3. The lower the temperature of the water, the greater the effectiveness of the disinfectant.
   1. True
   2. False
4. The resistance of microorganisms to specific disinfectants varies greatly.
   1. True
   2. False
5. Chlorine injected on the discharge side of a pump may cause pump corrosion problems.
   1. True
   2. False
6. The location of the chlorine injection point in a water system is very important.
   1. True
   2. False
7. Flushing is an effective way to disinfect water mains.
   1. True
   2. False
8. Hypochlorite (OCl^-) has a greater disinfection potential than hypochlorous acid ($HOCl$).
   1. True
   2. False
9. The flushing velocity for a water main after disinfection is more important than the flushing velocity before disinfection.
   1. True
   2. False
10. Whenever a new chlorine connection is made, always use a new gasket.
    1. True
    2. False
11. Chlorine gas is safer to handle than hypochlorite when disinfecting water.
    1. True
    2. False
12. When chlorine gas combines with moisture, the resulting mixture is corrosive.
    1. True
    2. False
13. Hypochlorite compounds are available in solid form only.
    1. True
    2. False

14. and 15. The reaction of chlorine gas with water tends to (14) ______ the pH of the water while sodium hypochlorite tends to (15) ______ the pH.

14. 1. Decrease
    2. Increase

15. 1. Decrease
    2. Increase

Multiple Choice

16. Alum usage can increase virus removals up to ______.
    1. 20%
    2. 50%
    3. 70%
    4. 90%
    5. 99%
17. Water mains should be flushed before disinfection by using a flushing velocity of at least ______.
    1. 0.5 ft/sec
    2. 1.0 ft/sec
    3. 1.5 ft/sec
    4. 2.0 ft/sec
    5. 2.5 ft/sec
18. The maximum rate of chlorine removal from a 150-pound cylinder is ______ pounds of chlorine per 24 hours.
    1. 20
    2. 40
    3. 50
    4. 80
    5. 100
19. Which of the following are safe procedures for handling chlorine cylinders?
    1. Keep cylinders close to direct heat to prevent freezing
    2. Move cylinders with a properly balanced hand truck
    3. Protective cap should always be in place when moving a cylinder
    4. Roll cylinders in a horizontal position
    5. Store cylinders on their sides
20. Which of the following precautions would you take when shutting down a hypochlorinator for a short duration?
    1. Lock out circuits
    2. Obtain another hypochlorinator
    3. Turn off gas
    4. Turn off hypochlorinator
    5. Turn off water supply pump

21. Factors influencing disinfection include
    1. Concentration of microorganisms.
    2. Hardness.
    3. pH.
    4. Temperature.
    5. Turbidity.

22. Pathogenic microorganisms are removed by which of the following water treatment processes?
    1. Coagulation
    2. Dilution
    3. Filtration
    4. Membrane filtration
    5. Sedimentation

23. If you were asked to review the specifications for disinfecting a water main by an outside contractor, which of the following items would you be sure were included in the contract specifications?
    1. Form of chlorine to be used
    2. Location of suitable drainage facilities
    3. Method of taking samples
    4. Rates of flushing
    5. Who is responsible for testing samples

24. Which of the following tasks should be checked daily under normal hypochlorinator operating conditions?
    1. Check chemical feed pump operation
    2. Check operation of check valve
    3. Measure chlorine residual in system
    4. Record gallons of water pumped
    5. Record level of solution in hypochlorite tank

25. An operator should never enter a room containing high concentrations of chlorine gas without
    1. A self-contained air supply.
    2. Help standing by.
    3. Notifying proper authorities.
    4. Notifying supervisor.
    5. Protective clothing.

26. Chlorine cylinders
    1. Can be handled safely.
    2. Can easily be lifted by one person.
    3. Contain a fusible metal safety plug.
    4. Should be kept away from steam pipes.
    5. Should be moved with the protective cap in place.

27. Which of the following laboratory test results are used to adjust the chlorine dose rate setting on a chlorinator?
    1. Chloride
    2. Chlorine residual
    3. Coliform
    4. Hardness
    5. TDS

28. What should be the chlorine dose of a water that has a chlorine demand of 2.5 mg/*L* if a residual of 0.4 mg/*L* is desired?
    1. 2.1 mg/*L*
    2. 2.3 mg/*L*
    3. 2.6 mg/*L*
    4. 2.9 mg/*L*
    5. 3.3 mg/*L*

29. What should be the setting on a chlorinator if a pump usually delivers approximately 700 GPM (assume 1 MGD) and the desired chlorine dose is 4.0 mg/*L*?
    1. 25 lbs. chlorine/24 hours
    2. 30 lbs chlorine/24 hours
    3. 33 lbs chlorine/24 hours
    4. 36 lbs chlorine/24 hours
    5. 40 lbs chlorine/24 hours

30. Water from a well is being disinfected by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 65 GPD and uses a 2.5 percent available chlorine solution, what is the chlorine dose rate in mg/*L*? The water pump delivers 400 GPM.
    1. 1.6 mg/*L*
    2. 2.4 mg/*L*
    3. 2.8 mg/*L*
    4. 3.1 mg/*L*
    5. 3.2 mg/*L*

31. A ten-inch water main 450 feet long needs to be disinfected. An initial chlorine dose of 400 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution will be needed.
    1. 3.4 gallons
    2. 5.7 gallons
    3. 10.7 gallons
    4. 13.4 gallons
    5. 14.0 gallons

32. How many gallons of 15 percent sodium hypochlorite solution will be needed to disinfect a reservoir 30 feet in diameter and 6-feet deep? An initial chlorine dose of 80 mg/*L* is expected to maintain a chlorine residual of over 50 mg/*L* during the 24-hour disinfection period.
    1. 9.1 gallons
    2. 13.7 gallons
    3. 15.2 gallons
    4. 16.9 gallons
    5. 18.8 gallons

33. Estimate the gallons of hypochlorite pumped by a hypochlorinator if the hypochlorite solution is in a container with a diameter of 30 inches and the hypochlorite level drops 26 inches during a specific time period.
    1. 69 gallons
    2. 80 gallons
    3. 86 gallons
    4. 88 gallons
    5. 95 gallons

34. Estimate the desired strength (as a percent chlorine) of a hypochlorite solution being pumped by a hypochlorinator that delivers 60 gallons per day. The water treated requires a chlorine feed rate of 15 pounds of chlorine per day.
    1. 3.0%
    2. 3.3%
    3. 8.0%
    4. 9.0%
    5. 9.9%

End of Objective Test

CHAPTER 7

SAFETY

by

Dan Saenz

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OBJECTIVES

Chapter 7. SAFETY

Following completion of Chapter 7, you should be able to:

1. *THINK SAFETY,*
2. Develop a safety program for a water utility agency,
3. Prepare and conduct tailgate safety sessions,
4. Safely operate and maintain pumps and wells, with attention to the safety of operators and consumers,
5. Work safely in streets,
6. Protect the motoring public and pedestrians from work areas in streets and sidewalks, and
7. Conduct a safety inspection of waterworks facilities.

GLOSSARY

Chapter 7. SAFETY

ACUTE ACUTE

Effects of an exposure which causes severe symptoms to occur quickly.

CHRONIC CHRONIC

Effects of an exposure which causes symptoms to continue for along time.

CONFINED SPACE* CONFINED SPACE

A space defined by the concurrent existence of the following conditions:

A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and

B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

Also see definitions of *DANGEROUS AIR CONTAMINATION* and *OXYGEN DEFICIENCY*.

DANGEROUS AIR CONTAMINATION DANGEROUS AIR CONTAMINATION

An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/or explosive, toxic or otherwise injurious or incapacitating substances.

A. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit.

B. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the minimum explosive concentration of the particulate.

C. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.

MATERIAL SAFETY DATA SHEET (MSDS) MATERIAL SAFETY DATA SHEET (MSDS)

A document which provides pertinent information and a profile of a particular hazardous substance or mixture. An MSDS is normally developed by the manufacturer or formulator of the hazardous substance or mixture. The MSDS is required to be made available to employers and operators whenever there is the likelihood of the hazardous substance or mixture being introduced into a workplace.

OXYGEN DEFICIENCY OXYGEN DEFICIENCY

An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

TAILGATE SAFETY MEETING TAILGATE SAFETY MEETING

The term *TAILGATE* comes from the safety meetings regularly held by the construction industry around the tailgate of a truck.

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* *CONFINED SPACES, General Industry Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service, Sacramento, California, October 1980.*

CHAPTER 7. SAFETY[1]

(Lesson 1 of 2 Lessons)

7.0 IMPORTANCE OF SAFETY

7.00 Think Safety

LET'S START THINKING SAFETY NOW! In this section we are going to provide you with some ideas for your safety program. The remaining sections of this chapter will discuss how to perform specific jobs safely. Two very important aspects of your safety program are:

1. Making people aware of unsafe acts, and
2. Conducting and/or participating in regular safety training programs.

7.01 What is Safety?

Webster states that safety is the following:

> "The condition of being safe; freedom from exposure to danger; exemption from hurt, injury or loss; to protect against failure, breakage or other accidents; knowledge of or skill in methods of avoiding accident or disease."

Safety is more than words. Safety is the action of Webster's definition. Safety is using one's knowledge or skill to avoid accidents or to protect one's self and others from accidents. Safety is a form of preventive maintenance which includes equipment and machinery and its proper handling. Who is responsible for safety? Everyone should be responsible from top management to all employees.

Safety is a program for everybody, not only on the job but also at home. Unfortunately, people miss more time at work from off-the-job accidents than from on-the-job accidents!

Management has its responsibilities for safety; its main function is to set the tone and provide the training and monies for an effective safety program. Management should be responsible for the following:

1. Establish a safety policy;
2. Assign responsibility for accident prevention, which includes description of the duties and responsibilities of a safety officer, department heads, line supervisors, safety committees and operators;
3. Appoint a safety officer or coordinator;
4. Establish realistic goals and periodically revise them to insure continuous and maximum effort; and
5. Evaluate the results of the program.

While management has its responsibilities, the operators also have their particular responsibilities. Operators should:

1. Perform their jobs in accordance with established safe procedures,
2. Recognize the responsibility for their own safety and that of fellow operators,
3. Report all injuries,
4. Report all observed hazards, and
5. Actively participate in the safety program.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 388.

7.0A List two very important aspects of a safety program.

7.0B What are management's responsibilities for safety?

7.0C What are the operators' responsibilities for safety?

7.1 SAFETY PROGRAM

7.10 Objective of Safety Program

A SAFETY PROGRAM HAS ONE OBJECTIVE: TO PREVENT ACCIDENTS. Accidents do not happen, they are caused They may be caused by unsafe acts of operators or result from hazardous conditions or may be a combination of both. An analysis of accident statistics reveals that operator negligence and carelessness are the causes of most accidents. We know how to do our job safely, but we just don't do it safely.

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[1] *Portions of this chapter include safety material developed and distributed by the Department of Water and Power, City of Los Angeles.*

Accidents reduce efficiency and effectiveness. An accident is that occurrence in a sequence of events that usually produces unintended injury, death or property damage. Accidents affect the lives and morale of operators. They raise the costs not only to management but also to operators.

7.11 Unsafe Acts

Safety authorities tell us that nine out of ten injuries are the result of unsafe acts of either the person injured or someone else. Here are some of the principal reasons for unsafe acts.

•IGNORANCE. This may be due to lack of experience or training, or to a temporary condition that prevents the recognition of a hazard.

•INDIFFERENCE. Some know better but don't care. They take unnecessary risks and disregard the rules or instructions.

•POOR WORK HABITS. Some people either don't learn the right way of doing things, or they develop a wrong way. Supervisors or fellow operators who see things done unsafely must speak up.

•LAZINESS. Laziness affects speed and quality of work. Laziness also affects safety, because safety requires an effort. In most jobs you cannot reduce your "safety effort" and still maintain the same level of safety, even if you slow down or lower your quality standards.

•HASTE. When we rush, we work too fast to think about what we are doing; we take dangerous shortcuts, and we are more likely to be injured.

•POOR PHYSICAL CONDITION. Some of us just won't take reasonable care of ourselves. We ignore our bodily needs in regard to exercise, rest and diet, lessening our endurance and alertness.

•TEMPER. Impatience and anger cause many accidents. Again, our thinking is interfered with and the way prepared for an accident.

Therefore, every one of these unsafe acts could be considered due to operator negligence or carelessness.

SAFETY QUOTE: THE MORE YOU TALK ABOUT SAFETY, THE LESS YOU HEAR ABOUT ACCIDENTS.

7.12 Driving Safety

Defensive drivers are safe drivers. Good drivers check and maintain vehicles properly, use the safety equipment, are courteous to other drivers, use proper signals in advance of any directional changes, and know and observe all traffic regulations. Defensive drivers always use seat safety belts and make sure that all lights — headlights, tail lights and directional lights — are operating correctly. Good drivers check to see that the tires are inflated to the proper pressure and that there are no bald spots or that the tires are not wearing unevenly. Brakes should be operating correctly. They should be able to stop your vehicle without grabbing or pulling to one side. Routine oil changes, observation of adequate coolant levels and tune ups should be performed periodically. The vehicle should be operated following the manufacturer's recommendations, observing your water utility's safe driving policies and observing all state and local driving regulations.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 388.

7.1A What is an accident?

7.1B How can you determine if the brakes on a vehicle are working properly?

7.1C List the principal reasons for unsafe acts.

7.1D What problems are caused by laziness?

7.13 Towing a Trailer

Frequently it is necessary to tow trailer-mounted equipment such as generators, compressors, and pumps. Towing a trailer requires experience, knowledge and a great amount of common sense. The job of towing a trailer seems to be a simple task; however, there are many pitfalls if good judgment is not exercised, or if the safety of others is not considered.

Many accidents related to trailer towing occur while simply coupling the trailer to the vehicle. Back strains and cuts and bruises to the hands and fingers are the injuries occurring before starting to tow a trailer.

The trailer and towing vehicle should be inspected and checked for the following:

1. Rear, turn signal, and brake lights,
2. Tire tread and inflation,
3. Wheel attachment (vandals may have loosened lug nuts),
4. Trailer brake operation if equipped with brakes,
5. Trailer hitch and tongue, and
6. Safety chain. After the trailer is coupled, the safety chain should be securely attached to the frame of the towing vehicle with enough slack to allow jack-knifing, but not enough to drag on the ground.

Once underway with a trailer in tow, the three items below are examples of when good judgment should be exercised:

1. Maximum speed for all vehicles is 55 mph — Remember that some trailers will not handle properly even at 45 mph.
2. Braking or stopping distances will increase if the trailer itself is not equipped with brakes.
3. Trailers make your vehicle much longer. Allow extra room when making turns, changing lanes or passing.

7.14 How to Charge a Battery

At one time or another you may have given a battery a boost or may have seen it done. There is a correct procedure to follow to eliminate damage to electrical components and to prevent a battery explosion (Figure 7.1).

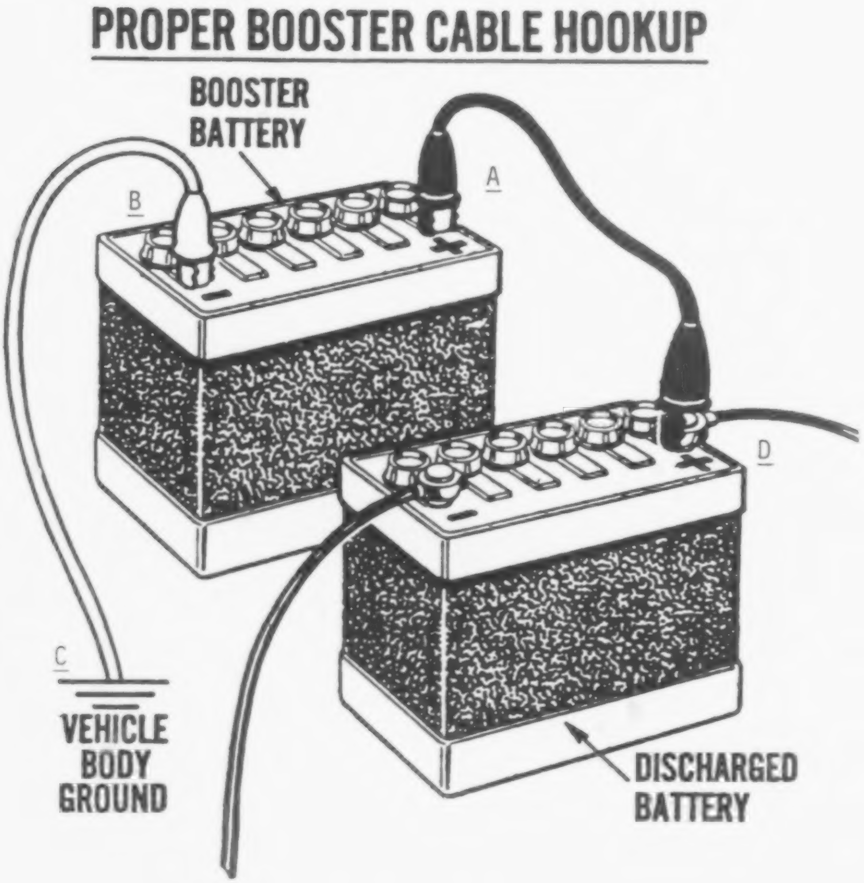

Fig. 7.1 *Proper booster cable hookup*

To boost the battery of a disabled vehicle from that of another vehicle, follow this procedure. First put out all cigarettes and flames. A spark can ignite hydrogen gas from the battery fluid. Next take off the battery caps, if removable, and add distilled water if it is needed. Check for ice in the battery fluid. Never jump-start a frozen battery! Replace the caps.

Next, park the auto with the "live" battery close enough so the cables will reach between the batteries of the two autos. The cars can be parked close, but do not allow them to touch. If they touch, this can create a dangerous situation. Now set each car's parking brake. Be sure that an automatic tranmission is set in park, put a manual-shift transmission in neutral. Make sure your headlights, heater, and all other electrical accessories are off (you don't want to sap electricity away from your dead battery while you are trying to start your car). If the two batteries have vent caps, remove them. Then lay a cloth over the open holes. This will reduce the risk of explosion (relieves pressure within the battery).

Attach one end of the jumper cable to the positive terminal of the booster battery (A) (that's the good battery in the other car) and the other end to the positive terminal of your battery (D). The positive terminal is identified by a + sign, a red color, or a "P" on the battery in your car. Each of the two booster cables has an alligator clip at each end. To attach, you simply squeeze the clip, place it over the terminal, then let it shut. Now attach one end of the remaining booster cable to the negative terminal of the booster battery (B). The negative terminal is marked with a − sign, a black color, or the letter "N." Attach the other end of the cable to a metal part on the engine of your car (C). Many mechanics simply attach it to the negative post of the battery. This is not recommended because a resulting arc could ignite hydrogen gas present at the battery surface and cause an explosion. Be sure the cables do not interfere with the fan blades or belts. The engine in the other car should be running, although it is not an absolute necessity.

Get in the disabled car and start the engine in a normal manner. After it starts, remove the booster cables. Removal is the exact reverse of installation. Remove the black cable attached to your engine, then remove it from the negative terminal of the booster battery. Then remove the remaining cable from the positive terminal of the "dead" battery and from the fill-holes. Replace the vent caps and you are done. Have the battery and/or charging system of the car checked by a mechanic to correct any problems.

For maximum eye safety, everyone working with car batteries or standing nearby should wear protective goggles to keep flying battery fragments and chemicals out of the eyes.

Should battery acid get into the eyes, immediately flush them with water continuously for 15 minutes. Then see a doctor.

The recommended procedure for jump-starting is listed, step by step, on a 4 inch by 8 inch yellow vinyl sticker which has a permanent adhesive. The sticker can be affixed to any clean, dry surface under the hood or kept inside the car's glove compartment. Stickers are available — 25¢ for one sticker, 12¢ for each additional one up to 100, $10 per 100, $80 per 1,000 — by writing the National Society to Prevent Blindness, Dept. B, 79 Madison Avenue, New York, NY 10016.

7.15 Boat Safety

Boats are commonly used in the operation of a water utility. They are used for sampling, surveying or inspecting reservoirs. Boats may be either motor operated (inboard or outboard) or rowboats. All boats should be inspected annually. The U.S. Coast Guard is usually the inspecting agency. They also recommend the safety practices to be used for boat safety. All boats should be equipped with a safety vest for each occupant or some type of approved flotation cushion. There should be oar-locks for the oars and oars should be of a suitable length for the respective boat and maintained in good operable condition. No boat should be loaded in excess of its loading capacity.

Motorized boats should meet the same conditions as rowboats. In addition the motors (inboard and outboard) should be maintained in good operating condition. Periodic tune ups and safety checks should be made following your utility's maintenance procedures or the manufacturer's recommendations. All motorized boats should have a set of oars to be used in an emergency and a fire extinguisher. At least two people should go out on a boat. If it is necessary that only one person use a boat, someone on shore should be aware that the person is out on the boat alone. Following safety practices when using boats could save someone from a potential drowning accident.

7.16 Corrosive Chemicals

A corrosive chemical is any chemical which may weaken, burn and/or destroy a person's skin or eyes. A corrosive chemical may be either acid or base (alkali). The pH scale from 0 to 14 is an indication of the strength of a solution. The "acids" with the low pH values are the most corrosive. Hydrochloric (HCl), nitric (HNO_3), and sulfuric (H_2SO_4) are among the strongest acids. A "base" with the highest pH values of around 13 are the most corrosive. Sodium hydroxide (NaOH) is a strong base. Some common chemicals which are corrosive are:

1. Ammonium hydroxide,
2. Calcium hypochlorite,
3. Chlorine,
4. Ferric chloride,
5. Hydrochloric acid,
6. Potassium permanganate,
7. Sodium chlorite,
8. Sodium hydroxide,
9. Sodium hypochlorite,
10. Sodium nitrate,
11. Sulfuric acid, and
12. Zinc orthophosphate.

This list is by no means complete.

Safety procedures must be followed in the handling and usage of all corrosive chemicals. Use safety protection equipment to protect your eyes and skin (see Section 7.21, "Protective Clothing"). Safety showers and eye/face wash should be installed at a location close to where any corrosive chemical is being used. Test the shower and eye/face wash at least once a week. Run the water using the emergency levers (the pull chains, hand-actuated valves or treadle foot-actuated valves). Let the water run for approximately three to five minutes or until the water runs clear. Rust may be in the water lines and may increase the problem of washing chemicals from your eyes.

7.17 Tailgate Safety Sessions

Tailgate safety sessions are so called because the session consists of a small group of operators gathered around the tailgate of a pickup or truck to discuss safety. These sessions are usually held near the work site and new and old safety hazards and safer approaches or techniques to deal with the problems of the day or week are discussed. The amount or degree of organization or formality of the sessions depends on the types of safety problems and what you think is the most effective way of educating your crew. Table 7.1 is a typical topic for a tailgate safety session.

TABLE 7.1 TAILGATE SAFETY TOPIC

Most injuries that happen on water utility jobs are caused directly by the injured person. Only a small percent are caused by defective equipment or devices. Because of this, you must be primarily responsible for your own safety.

Management and supervision are usually regarded as being the ones responsible for safety. Without proper interest on the part of management and supervision, a total safety program can't be effective. But you must realize that you, more than anyone else, are responsible for not only your own safety but for the safety of your fellow operators. In other words, you must be your "brother's keeper."

Here's an example of what we're trying to say. Management can purchase new trucks and equip them with all the known safety devices and maintain them in perfect operating condition. But a truck has to be operated by a driver (you); you alone are responsible for its safe operation so that neither you nor any of your fellow operators will get hurt.

Here's another example. Take the simple wooden ladder. The ladder may be built to the best safety specifications; it may have been properly stored and frequently inspected for defects. Somebody, however, must place the ladder in position and somebody must use it. If it's not properly placed, if the footing is insecure, if it hasn't been secured to the building by some individual, it is entirely likely that the person using it or some other operator will get hurt. And how can either management or supervision be held responsible for such accidents? You must realize that you are the most vital factor in the control of accidents.

Some operators seem to think that the safety officer is responsible for preventing accidents. Even though the safety officer frequently makes inspections and counsels the operators and supervisors, the safety operator can't be in all places at all times. And the safety officer cannot, therefore, be blamed or held responsible whenever an accident occurs. So let's bear in mind that we ourselves, as individuals, must constantly be alert to the hazards around us. If we can't remove a hazard ourselves, we should call it to the attention of those who have the authority to do so.

7.18 Employee "Right-To-Know" Laws

Employee "Right-To-Know" legislation has been implemented to require employers to inform employees (operators) of the possible health effects resulting from contact with hazardous substances. At locations where this legislation is in force, employers must meet certain requirements. Employers must provide operators with information regarding any hazardous substances which the operators might be exposed to under either normal work conditions or reasonably foreseeable emergency conditions resulting from workplace conditions. Information regarding hazardous substances is available from manufacturers in the form of Material Safety Data Sheets (MSDS) for hazardous substances. Employers must provide operators with a copy of MSDSs upon request and also must train operators to work safely with the hazardous substances that are encountered in the workplace.

As an operator you have the right to ask your employer if you are working with any hazardous substances. If you work with any hazardous substances, your employer must provide you with information on the health implications resulting from contact with the substances, the Material Safety Data Sheets, and training for working safely with the hazardous substances.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 388.

7.1E List the items that should be inspected before towing a trailer.

7.1F Why should all cigarettes and flames be put out before attaching cables to charge a battery?

7.1G List the safety practices for using boats.

7.1H What is a corrosive chemical?

7.1I What is a tailgate safety session?

7.2 PERSONAL SAFETY

Personal safety goes hand-in-hand with a good, effective safety program. You are the key individual to an effective safety program.

Don't you, as an operator, become a statistic

Table 7.2 is a tabulation of the types of accidents encountered in the water utility field. This chapter will provide you with safe procedures which will help you avoid becoming an accident statistic.

TABLE 7.2 ANALYSIS OF ACCIDENT TYPES[a]

	Percent
1. Sprains/strains in lifting, pulling or pushing objects	28
2. Sprains/strains due to awkward position or sudden twist or slip	16
3. Struck by falling or flying objects	10
4. Struck against stationary or moving objects	9
5. Falls to different level from platform, ladder, stairs	7
6. Caught in, under or between objects	6
7. Falls on same level to working surface	5
8. Contact with radiations, caustics, toxic and noxious substances	3
9. Animal or insect bites	1
10. Contact with temperature extremes	1
11. Rubbed or abraded	1
12. Contact with electric current	0
13. Miscellaneous	11

[a] AWWA Safety Bulletin

7.20 Monitoring Equipment

There are many locations in a water utility where it is necessary to monitor the atmosphere before entering. Some of these specific locations may be underground regulator vaults, solution vaults, manholes, tanks, trenches and other *CONFINED SPACES*[2] (also see Section 7.63, "Confined Spaces"). There are a variety of devices that are used to monitor (check) the available oxygen and also combustible and toxic gases. Regardless of what type of monitoring device or devices are used, you should always test for *DANGEROUS AIR CONTAMINATION*[3] and/or *OXYGEN DEFICIENCY*[4] with an approved device immediately prior to an operator entering a confined space and at intervals frequent enough to insure a safe atmosphere during the time an operator is in the structure. Dangerous air contamination includes explosive conditions and toxic gases. Toxic gases include hydrogen sulfide and carbon monoxide. *A RECORD OF THE TEST MUST BE KEPT AT THE JOB SITE* for the duration of the work. *YOUR LIFE* and that of *YOUR FELLOW OPERATORS* is in jeopardy if the air in a confined space is not tested before entering. The following four steps should be performed before entering a confined space:

1. *CALIBRATE* the gas detection device,
2. *BARELY OPEN* the confined space,
3. *TEST* for combustible and toxic gases and oxygen deficiency using a probe or tube to collect the sample,
4. *RECORD* the results of these tests in your gas log, and
5. *VENTILATE* the confined space.

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[2] *Confined Space.*[a] *A space defined by the concurrent existence of the following conditions:*
- *A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and*
- *B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).*

[3] *Dangerous Air Contamination. An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/or explosive, toxic or otherwise injurious or incapacitating substances.*
- *A. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit.*
- *B. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the minimum explosive concentration of the particulate.*
- *C. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.*

[4] *Oxygen Deficiency. An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.*

[a] *CONFINED SPACES, General Industrial Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service, Sacramento, California, October 1980.*

If a hazardous atmospheric condition is discovered, you must repeat the tests for combustible and toxic gases and oxygen deficiency while ventilating and again *RECORD* the results.

On rare occasions, unusual conditions may exist or be created even though the required testing procedures have been followed. Air currents through duct lines can easily change if other vaults in the same system are opened. Toxic or explosive gases from broken gas lines or decayed vegetation may then flow through the ducts into a previously gas-free vault. Therefore it is important that *ADEQUATE VENTILATION BE MAINTAINED AND THAT THE SPACE BE RECHECKED FOR HAZARDOUS ATMOSPHERES PERIODICALLY WHILE OPERATORS ARE WORKING IN SUCH LOCATIONS.* Use portable fans or ventilators to provide fresh air.

At least one person must stay outside the confined work area. This standby person should check continuously on the status of personnel working in the confined space. Should a person working in the confined space be rendered unconscious due to asphyxiation or lack of oxygen, the standby at the surface could descend into the space by:

1. Securing a back up rescue person, and
2. Donning the correct type of respiratory protective equipment.

Self-contained breathing equipment should be nearby and used as necessary.

Follow the procedures outlined in the *SAFETY NOTICE* whenever anyone must enter a confined space.

SAFETY NOTICE

Before anyone ever enters a tank for any reason, these safety procedures must be followed:

1. Test atmosphere in the tank for toxic and explosive gases and for adequate oxygen. Contact your local safety equipment supplier for the proper types of atmospheric testing devices. These devices should have alarms which are activated whenever an unsafe atmosphere is encountered;
2. Provide adequate ventilation, especially when painting. A self-contained positive-pressure breathing apparatus may be necessary when painting;
3. All persons entering a tank must wear a safety harness, and
4. One person must be at the tank entrance and observing the actions of all people in the tank. An additional person must be readily available to help the person at the tank entrance with any rescue operation.

Table 7.3 lists some common dangerous gases which may be encountered by the operators of water supply systems and water treatment plants.

The "proper" mixture of oxygen with a gas is necessary to create explosive or flammable conditions. If there is not enough gas present (too much oxygen), the mixture is too lean and will not burn or explode. Also, if there is too much gas (not enough oxygen), the mixture is too rich and will not burn or explode. The range of explosive or flammable gas mixtures is defined by the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). The objective of gas detection equipment is to warn us when we encounter explosive conditions within 20 percent of the Lower Explosive Limit.

Anytime a gas mixture is within 20 percent of the Lower Explosive Limit, this is considered a hazardous condition.

Figure 7.2 shows the relationship between the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL) of a mixture of air and gas. Note in Table 7.3 that the percent by volume of a gas in air for the Lower Explosive Limit to occur is different for each gas. Also note in Figure 7.2 that if you have all gas (100% gas and 0% oxygen), the mixture is too rich and will not explode. If a mixture of gas and oxygen from the air is greater than 20 percent of the Lower Explosive Limit, the mixture is considered hazardous.

Monitoring equipment is essential to protect you from hazardous atmospheres when entering and working in enclosed spaces. This type of monitoring equipment is available in three different types;

1. Portable and attached to your clothing or your body,
2. Portable and carried by you or placed near your work site, and
3. Permanently installed in locations where hazardous atmospheres could develop.

You may encounter three types of hazardous atmospheres:

1. Toxic gases such as chlorine, carbon monoxide or hydrogen sulfide,
2. Explosive or flammable conditions, and
3. Oxygen deficiency.

Regardless of the type of detection devices that you are using to monitor hazardous atmospheres, regularly calibrate the detection devices according to manufacturer's recommendations. These calibration procedures must be scheduled and performed as part of your preventive maintenance program. Remember, the detection devices are sensitive instruments. Handle them gently and keep them accurate if you wish to stay alive.

The recommended warning devices should be an audible noise and/or a flashing light that should start whenever a hazardous condition is detected. An operator should not be expected to read a meter while working and decide whether or not a hazard exists.

Sometimes operators working in small communities or for small agencies experience problems convincing their supervisors of the need for gas detection devices, portable ventilators, safety harnesses, and qualified people standing by when they must enter tanks, vaults and manholes. OSHA regulations allow operators to refuse to perform work under unsafe conditions. This is a very difficult situation. We recommend that operators contact their local or state OSHA

TABLE 7.3 COMMON DANGEROUS GASES ENCOUNTERED IN WATER SUPPLY SYSTEMS AND AT WATER TREATMENT PLANTS

Name of Gas	Chemical Formulae	Specific Gravity of Vapor Density** (Air = 1)	Explosive Range (% by volume in air)		Common Properties (Percentages below are per cent in air by volume)	Physiological Effects (Percentages below are per cent in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing †
			Lower Limit	Upper Limit				
Oxygen (In Air)	O_2	1.11	Not flammable		Colorless, odorless, tasteless, non-poisonous gas. Supports combustion.	Normal air contains 20.93% of O_2. Man tolerates down to 12%.* Below 5 to 7% likely to be fatal.	Oxygen depletion from poor ventilation and absorption or chemical consumption of available O_2.	Oxygen deficiency indicator.
Gasoline Vapor	C_5H_{12} to C_9H_{20}	3.0 to 4.0	1.3	7.0	Colorless, odor noticeable in 0.03%. Flammable. Explosive.	Anesthetic effects when inhaled. 2.43% rapidly fatal. 1.1% to 2.2% dangerous for even short exposure.	Leaking storage tanks, discharges from garages, and commercial or home dry-cleaning operations.	1. Combustible gas indicator. 2. Oxygen deficiency indicator for concentrations over 30%.
Carbon Monoxide	CO	0.97	12.5	74.2	Colorless, odorless, non-irritating, tasteless, Flammable. Explosive.	Hemoglobin of blood has strong affinity for gas causing oxygen starvation. 0.2 to 0.25% causes unconsciousness in 30 minutes.	Manufactured fuel gas.	CO ampoules.
Hydrogen	H_2	0.07	4.0	74.2	Colorless, odorless, tasteless, non-poisonous, flammable. Explosive. Propagates flame rapidly; very dangerous.	Acts mechanically to deprive tissues of oxygen. Does not support life. A simple asphyxiant.	Manufactured fuel gas.	Combustible gas indicator.
Methane	CH_4	0.55	5.0	15.0	Colorless, tasteless, odorless, non-poisonous. Flammable. Explosive.	See hydrogen.	Natural gas, marsh gas, mfg. fuel gas, sewer gas.	1. Combustible gas indicator. 2. Oxygen deficiency indicator.
Hydrogen Sulfide	H_2S	1.19	4.3	46.0	Rotten egg odor in small concentrations but sense of smell rapidly impaired. Odor not evident at high concentrations. Colorless. Flammable. Explosive. Poisonous.	Death in few minutes at 0.2%. Paralyzes respiratory center.	Petroleum fumes, from blasting, sewer gas.	1. H_2S analyzer. 2. H_2S ampoules.
Carbon Dioxide	CO_2	1.53	Not flammable		Colorless, odorless, non-flammable. Not generally present in dangerous amounts unless there is already a deficiency of oxygen.	10% cannot be endured for more than a few minutes. Acts on nerves of respiration.	Issues from carbonaceous strata. Sewer gas.	Oxygen deficiency indicator.
Nitrogen	N_2	0.97	Not flammable		Colorless, tasteless, odorless. Non-flammable. Non-poisonous. Principal constituent of air (about 79%).	See hydrogen.	Issues from some rock strata. Sewer gas.	Oxygen deficiency indicator.
Ethane	C_2H_4	1.05	3.1	15.0	Colorless, tasteless, odorless, non-poisonous. Flammable. Explosive.	See hydrogen.	Natural gas.	Combustible gas indicator.
Chlorine	Cl_2	2.5	Not flammable Not explosive		Greenish yellow gas, or amber color liquid under pressure. Highly irritating and penetrating odor. Highly corrosive in presence of moisture.	Respiratory irritant, irritating to eyes and mucous membranes. 30 ppm causes coughing. 40-60 ppm dangerous in 30 minutes. 1000 ppm apt to be fatal in few breaths.	Leaking pipe connections. Overdosage.	Chlorine detector. Odor, strong. Ammonia on swab gives off white fumes.

** Gases with a specific gravity less than 1.0 are lighter than air; those more than 1.0 heavier than air.

† The first method given is the preferable testing procedure.

* Never enter a 12% atmosphere. Use detection meters with alarm warning devices rather than meters.

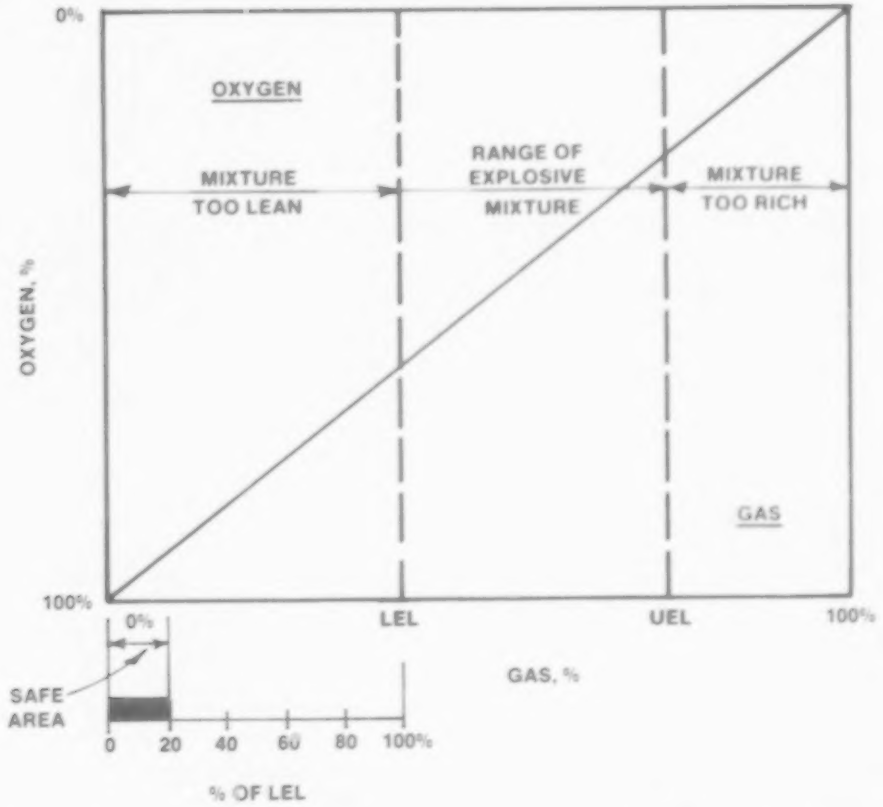

Fig. 7.2 Relationship between Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL)

officials or other industrial safety officials. Obtain copies of the rules and regulations for entering tanks and confined spaces (see Section 7.63, "Confined Spaces"). These regulations usually specify the conditions which must be monitored. More important, however, is that these regulations will specify the penalties imposed on supervisors and employers for failing to provide operators with the proper safety equipment, procedures and training. These penalties include stiff fines and jail sentences. Responsible employers and supervisors would rather comply with safety regulations than pay fines and spend time in jail.

OPERATORS HAVE THE RIGHT TO REFUSE TO DO ANYTHING THAT ENDANGERS THEIR LIVES.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 388.

7.2A List the typical locations in a water utility where it is necessary to monitor the atmosphere before entering.

7.2B Why should a standby person stand outside the confined work area?

7.2C At what level is a mixture of air and gas considered hazardous?

7.21 Protective Clothing (Figure 7.3)

Protective clothing is required for the protection of operators. Some clothing may be the responsibility of each operator and other protective equipment may be supplied by the water utility. Typical protective equipment supplied by the operators may be:

1. Safety toe (hard toe) shoes, and
2. Safety prescription glasses.

Protective equipment which may be required or supplied includes:

1. Safety (hard) hats,
2. Ear plugs,
3. Safety glasses (non-prescription),
4. Safety goggles,
5. Face shields,
6. Respirators and masks,
7. Canvas gloves,
8. Rubber gloves for use with corrosive chemicals,
9. Safety aprons,
10. Leggings/knee pads/safety belts or harnesses,
11. Safety toe caps, and
12. Protective clothing (lab coats or rubber suits).

Protective clothing must be worn and equipment used (as appropriate) whenever *YOU* are exposed to safety hazards as you do your job.

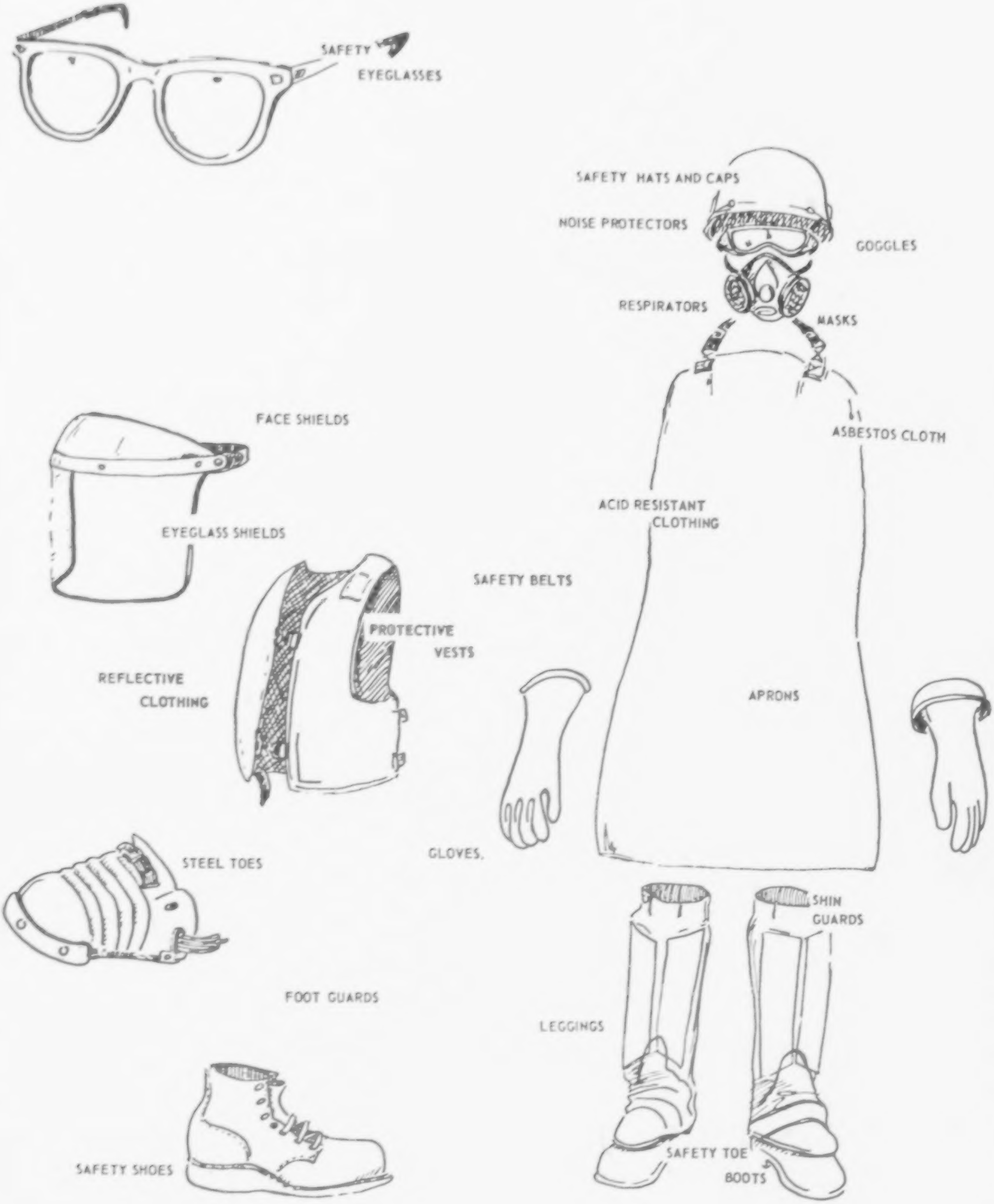
SAFETY EYEGLASSES
SAFETY HATS AND CAPS
NOISE PROTECTORS
GOGGLES
RESPIRATORS
MASKS
FACE SHIELDS
ASBESTOS CLOTH
ACID RESISTANT CLOTHING
EYEGLASS SHIELDS
SAFETY BELTS
PROTECTIVE VESTS
REFLECTIVE CLOTHING
APRONS
STEEL TOES
GLOVES.
SHIN GUARDS
FOOT GUARDS
LEGGINGS
SAFETY SHOES
SAFETY TOE BOOTS

Fig 7.3 Protect all of you

7.22 Slips and Falls

Slips and falls are common accidents which can be a major problem in a water utility. All floors should be level and kept as slip resistant as possible. Floors should be free of all debris. Material that drips or spills can be collected in drip pans, appropriate gutters, or splash guards may be used to deflect drips. If liquids do get on floors, nonflammable absorbent materials should be available for cleaning up.

CAUTION: Sawdust should never be used as an absorbent because it is combustible.

When cracks, splinters, ruts or breaks occur in floors they should be repaired as soon as possible. Good housekeeping and maintenance go hand in hand to prevent slips and falls. If water and chemicals spill on the floor, they should be wiped up as soon as possible. Catwalks or safety tread may be necessary on floors where water or chemicals are commonly spilled. The catwalk or safety tread will help prevent unnecessary slips and falls.

All stairways and elevated catwalks should have safety railings. Approved caution signs should be used where necessary to call attention to potential hazards or remind operators to use caution or to use safety equipment.

SAFETY QUOTE: Falls cause more accidents than summers, winters or springs.

7.23 Handling and Lifting

Injuries caused by handling and lifting are many and varied. Approximately 28 percent of operator injuries can be directly attributed to the handling of objects. A large portion of strains and sprains, fractures and bruises, back injuries and hernias are the result of common handling injuries. These injuries are caused primarily by unsafe work practices such as:

1. Improper lifting,
2. Carrying too heavy a load,
3. Incorrect gripping,
4. Failing to observe proper foot or hand clearance, and
5. Failing to use or wear proper equipment.

Many of us do not think much of lifting but if we are lifting an object incorrectly, we may suffer bad results such as pulled muscles, disc lesions or painful hernias. Remember Figure 7.4 whenever you have a lifting job.

Here are seven steps to safe lifting:

1. Keep feet parted — one along the side of and one behind the object,
2. Keep back straight — nearly vertical,
3. Tuck your chin in,
4. Grip the object with the whole hand,
5. Tuck elbows and arms in,
6. Keep body weight directly over feet, and
7. Lift slowly.

Safety equipment should be used to help protect your body. To protect your hands, use the gloves; and your feet, safety shoes, instep protectors, and ankle guards. Size the weight of objects you must lift. Never lift more than you can safely carry. Use handles or holders that attach to the objects such as handles for moving auto batteries or baskets for carrying laboratory samples. If the object to be moved is awkward or too large or heavy for one operator, have two operators move the object in question. When more than one operator is used, the object to be lifted must be lifted in unison (all at once) and everyone must know how the object is to be lifted and handled. Only one operator is assigned the task of giving orders as necessary such as when to start, lift, carry and set down the object. All parties concerned should lift correctly with the legs bearing the bulk of the physical effort.

If the object to be lifted and handled is too heavy for a person or persons to move safely, then use hand trucks, dollies, or powered hand trucks to move and/or lift objects.

Remember, 28 percent of injuries are caused by improper lifting and handling. Your health and safety depends on you using correct lifting and handling procedures.

7.24 Electrical

Electrical safety is very important to your life. Whenever you must work on electrical equipment or equipment that is run by electric motors, be sure to lock out and tag all of the electrical switches. Only you should ever be allowed to remove a lockout device and tag that you have installed. Also you should never remove a tag or lockout device installed by another operator.

Water is a good conductor of electricity. Do not stand in water when working on electrical equipment.

Throughout this manual we have outlined safe procedures to follow whenever you must operate or maintain electrical equipment or equipment run by electrical motors.

Many water supply and water treatment monitoring, measuring and control systems are electrical. Always be very careful when working around or troubleshooting these instrumentation systems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 388.

7.2D List as many items of protective clothing for operators as you can recall.

7.2E How can liquids spilled on floors be cleaned up?

7.2F List the steps to safe lifting.

7.2G What precautions should be taken when working on electrical motors?

7.3 SAFETY AROUND WELLS

7.30 Importance of Well Safety

Safety around wells is important for two reasons:

1. Safety control around the well site is necessary to prevent contamination or pollution of the well which could affect the health and safety of the consumer, and
2. Safety housekeeping of the site will help prevent an accident to operators or employees working near or around the well.

The well operator has the responsibility to preserve the quality of the well through preventive maintenance of the area where the well is located.

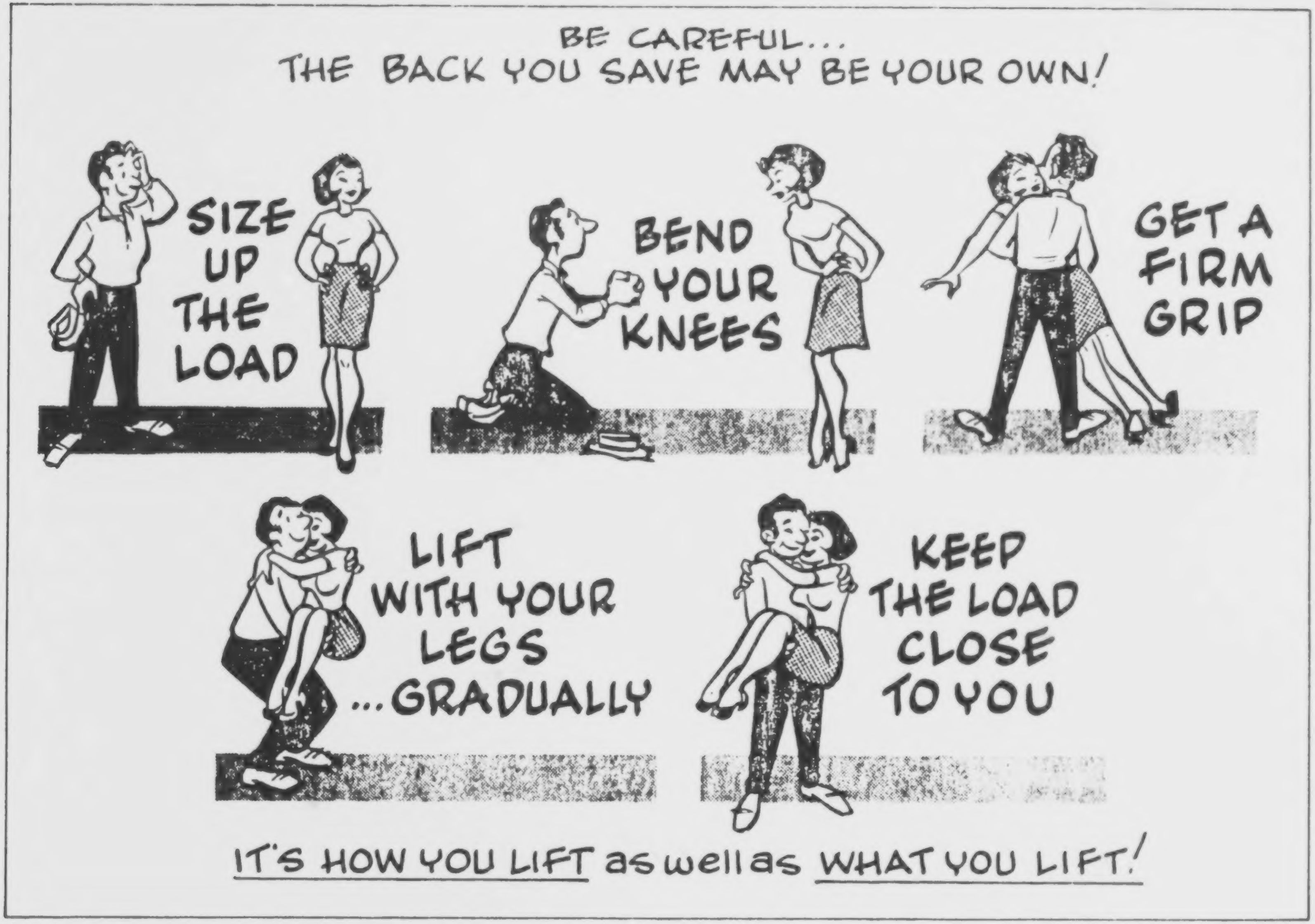
BE CAREFUL...
THE BACK YOU SAVE MAY BE YOUR OWN!
SIZE UP THE LOAD
BEND YOUR KNEES
GET A FIRM GRIP
LIFT WITH YOUR LEGS ...GRADUALLY
KEEP THE LOAD CLOSE TO YOU
IT'S HOW YOU LIFT as well as WHAT YOU LIFT!

Fig. 7.4 Lifting

(Reproduced from *OPERATION OF WASTEWATER TREATMENT PLANTS*, published by Foundation of California State University, Sacramento)

7.31 Location of Well Site

Selection of a well site requires serious consideration of several factors. The well should be located a suitable distance from any potential pollution source which may affect the groundwater. Some potential sources of pollution may be septic tanks, subsurface leaching systems, mining operations, solid and hazardous waste disposal sites and wastewater treatment facilities.

Some wells have been located in areas where initially the environment was correct for the site. The following are examples of well sites which were contaminated after a well had been in operation for some time.

EXAMPLE 1

A Girl Scout Camp leased a camp in the Angeles National Forest. This camp had two wells which supplied all the drinking water. The two wells were located in a small, narrow, secluded valley and for several years the bacteriological samples were negative. Camp officials decided to purchase horses to provide a special camping session where the camper could specialize in equestrian events. After a few years the well water bacteriological samples began to turn up positive. This water even had positive coliform samples with chlorination. After an investigation it was determined that the well was being contaminated because the horse stables were located above the well. During the rainy season the rain washed the horse manure down into the wells located below the stables.

EXAMPLE 2

A utility began to cut personnel because of fiscal problems. Some of the first cuts affected gardening personnel who cleaned up around the well site. After a few months the area around the well site became a dumping site. Old lumber, furniture, sofas, chairs, and garden clippings began to pile up around the well site. This debris attracted rodents; rats, ground squirrels and snakes close to the well site. This caused a potential problem to the employees and to the utility's consumers.

7.32 New Wells

No sewers should be permitted with 50 feet (15 m) of any well. If the well must be located within 100 feet (30 m) of a sanitary or storm sewer under gravity flow, special pipe and fittings must be used (see Chapter 3, "Wells," Section 3.15, "Well Site Selection").[5] This is necessary to prevent intrusion of leaking wastewater into the well.

7.33 Sanitary Seal

The sanitary seal on a well is the most important factor to prevent contamination of any type of well. This seal will prevent contaminated water or debris from entering around the well casing and into the water (review Chapter 3, "Wells," Section 3.14, "Well Structure and Components") in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

When applying disinfectant or using well cleaning agents, the operator must protect the well against the entrance of surface water or foreign matter.

7.34 Surface Portion of Well

All surface openings installed on top of a well must be protected against the entrance of surface water or foreign matter. Well casing vents should be constructed so that openings are in a vertical downward position. They should be a minimum of 36 inches (90 centimeters) in height above the finished surface of the well lot (ground surface) and should be covered with a fine mesh or device to exclude small insects from the inside of the well.

Gravel tubes must be capped at the top end, kept tightly sealed and elevated above ground level to prevent flood waters from entering the well.

The sounding tube must be kept tightly sealed. All pipe vents, sounding lines, and gravel fill pipes must be continuous conduit through the concrete pedestal. Also, all conduits which penetrate the casing must be provided with a continuous water tight weld at the point of entry into the well interior. A pump motor base seal must be water tight. All these safety requirements are necessary to insure that contaminants do not get into the well's interior. When these safety features are incorporated in a well's construction, the probability is lessened that the well will be contaminated by surface debris or waters. Review Chapter 3, "Wells," Section 3.1, "Surface Features of a Well" in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

7.35 Tank Coatings

Hydropneumatic pressure tanks incorporated with wells are normally painted on the interior surface with a protective coating to extend the life of the tank. Special consideration must be used in selecting the proper type of coating. The coating should be approved by the AWWA or the Additives Evaluation Branch of EPA and not be a cause of pollution or contamination of the drinking water. The application procedures are most important and the curing time is essential for proper results.

CAUTION

When applying a coating — personnel should use forced ventilation and/or a protective mask with an air line to provide an adequate air supply that is safe to work in. Coatings used in tanks are *VOLATILE* and can affect the respiratory system.

When applying coating, at least two operators should work together — one inside the tank and the other close by. The operator outside checks on the status of the person working inside and checks periodically on the forced ventilation system and air pressure for the air mask, if used. A third person must be readily available to assist the person outside with any rescue operations. See *SAFETY NOTICE.*

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[5] *Check with your local health department for distances which apply to your well.*

SAFETY NOTICE

Before anyone ever enters a tank for any reason, these safety procedures must be followed:

1. Test atmosphere in the tank for toxic and explosive gases and for adequate oxygen. Contact your local safety equipment supplier for the proper types of atmospheric testing devices. These devices should have alarms which are activated whenever an unsafe atmosphere is encountered;
2. Provide adequate ventilation, especially when painting. A self-contained positive-pressure breathing apparatus may be necessary when painting;
3. All persons entering a tank must wear a safety harness; and
4. One person must be at the tank entrance and observing the actions of all people in the tank. An additional person must be readily available to help the person at the tank entrance with any rescue operations.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.3A What are the safety responsibilities of the well operator?

7.3B How is contaminated water or debris kept from entering around the well casing and reaching the groundwater?

7.3C List the surface openings on top of a well that must be protected against the entrance of surface water or debris into the well.

7.36 Well Chemicals

7.360 Acid Cleaning

An acid treatment may be necessary to loosen incrustations from a well casing and well. Normally hydrochloric or sulfamic acids are used. Hydrochloric (HCl) acid should be used at full strength. Hydrochloric acid can be introduced into a well by means of a wide-mouthed funnel and a ¾- or 1-inch (16 or 25 mm) place pipe. Extend the place pipe into the well and attach the funnel to the end outside of the well. Pour the acid into the funnel and allow it to run into the well. If hydrochloric acid (muriatic acid — industrial name) is used, be careful! The pH of hydrochloric acid is approximately 1.0. This acid is very corrosive.

Inhalation of hydrochloric acid fumes can cause coughing, choking, and inflammation of the entire respiratory tract.

Swallowing even a small amount of this acid can cause corrosion of mucous membranes, esophagus and stomach; difficulty swallowing; nausea; vomiting; intense thirst; and diarrhea. Circulatory collapse and death may occur.

Hydrochloric acid causes severe skin burns. Spills, splashes or fumes may affect the eyes and could cause permanent eye damage.

Safety apparatus must be used when working with hydrochloric acid. Protective clothing includes rubber gloves, preferably long for hands — approximately 15 to 18 inches (38 to 45 cm), rubber apron for clothes protection, boots for foot protection in case of spillage, and face shield for protection against splashes and fumes.

Extreme care should be used in transporting acid. Acid should be carried in cases (gallons) or in carboys for protection and must be placed securely in a vehicle whenever transported.

Sulfamic acid has advantages over hydrochloric acid. Sulfamic acid may be used in granular form or as an acid solution mixed on site. Granular sulfamic acid is non-irritating to dry skin and its solution gives off no fumes except when reacting with incrusting materials. Spillage, therefore, presents no hazard and handling is easier, cheaper and safer.

Although sulfamic acid is non-irritating to dry skin and it gives off no fumes, rubber gloves should still be used because hands may become wet from perspiration and the acid will cause burns on the skin. Safety goggles or glasses, preferably a face shield, should be used in case granules are blown into the face and/or the eyes. If sulfamic acid is mixed on site, care should be used in mixing.

CAUTION

Acid should always be added slowly to the water. Use an acid-proof crock for mixing. Mix with a wooden paddle or electric mixer. Again, always use rubber gloves, rubber boots, a rubber apron and a face shield when mixing sulfamic acid.

NEVER ADD WATER TO ACID. ACID COULD SPLASH ALL OVER YOU.

When using any *CORROSIVE* or *CAUSTIC* chemical, an eye/face wash station must be available in case of an emergency. There are a variety of portable eye/face wash units commercially available. The unit should be located at a site which has easy access in case it is needed, preferably within 20 feet (6 m) of where the acid is being used. All personnel concerned should know the location of the eye/face wash station and be instructed on how to use it.

If anyone spills acid on their skin, the exposed area should be washed down with water as soon as possible. Also, they should change their clothes and shower if necessary. If acid is splashed on the face or in the eyes, immediately wash face/eyes with eye wash for at least 15 minutes. Make sure the eyes are thoroughly flushed with water. If irritation continues, resume washing eyes with water. Keep eyes moist with a wet towel and have a physician examine for further treatment.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.3D Why must hydrochloric acid be handled carefully?

7.3E What are the advantages of using sulfamic acid over hydrochloric acid to acid clean a well?

7.3F What safety precautions should be used when working with sulfamic acid in the granular form?

7.361 Chlorine Treatment

When a well requires treatment with chlorine, either granular calcium hypochlorite or liquid sodium hypochlorite is commonly used. Regardless of the type of hypochlorite used, safety equipment should be used. Again, use rubber gloves, preferably 15 to 18 inches (38 to 45 cm) long, a rubber apron, rubber boots and a face shield to protect against splashes. A portable eye/face wash should be available in case of splashes. Wear a "nuisance mask" when working with granular or powdered chemicals because these dusts can be harmful.

Use caution in the transfer of hypochlorite compounds. They should be transferred in their original containers and handled with care. Operators must be trained in the use of calcium and sodium hypochlorite products. Follow manufacturers' recommendations or your utility's safety policy.

CAUTION

When using acid or chlorine products, be mindful of the dangerous potential that fumes may have. Therefore, whenever using an acid or a chlorine product, use them where there is adequate ventilation. If necessary, use a forced ventilation system in pump houses or confined spaces.

When working with chemicals around a well, keep all personnel out of pits or depressions around the well. During treatment some of the toxic gases, such as hydrogen sulfide, may rise from the well and settle in the lowest areas nearby because these gases are usually heavier than air.

7.362 Polyphosphate

Sodium polymetaphosphate is a chemical sometimes added to wells. This chemical may be sold commercially as Graham's salt, "Sodium hexametaphosphate," glassy sodium metaphosphate, or Hy-Phos $(NaPO_3)x$. The chemical is clear, hygroscopic (attracts moisture from the air), soluble in water, but it dissolves slowly in water. The chemical is supplied in the form of a powder, flake, or as small, broken glass-like particles which possess dispersing and deflocculating properties.

CAUTION

Glassy phosphate consists of broken glass particles which are very sharp and can cut your skin. Use heavy-duty gloves when handling. Respiration equipment or a face shield should be used.

An eye/face wash should be available if solution is splashed into the face or eyes. Wash face continuously for 15 minutes. Get medical attention.

7.363 Disinfection of Wells and Pumps

Care should be taken during the construction of new wells. All pipes used in the construction of a well should be as clean as possible. Regardless of how clean the pipe for the well casing is kept, a new well pump should be disinfected. This disinfection is necessary because contamination could be introduced into the well from the drilling tools and mud, make up water, topsoil falling into or sticking to tools, and from the gravel itself.

Disinfect a well or well pump with a chlorine solution strong enough to produce a chlorine concentration of 50 mg/*L* in the well casing. Use caution when disinfecting wells and pumps. Follow safety procedures listed under chlorine treatment in this chapter. Also refer to Chapter 3, Section 3.5, "Disinfection of Wells and Pumps" in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

7.37 Working Around Electrical Units

Electricity is supplied as an alternating current (A.C.) at 120, 240, or 480 volts. Most wells or large pumps will be energized by 240 or 480 volts. Extremely large pumps may be energized by even higher voltages. Place nonconducting rubber mats on the floor in front of all power panels and motor control centers.

Care and caution should be used when working around equipment that is hooked up to any electrical current.

When maintenance is to be done on wells or pumps, lock out the electrical current to the equipment. Open the breakers so that electrical current is turned off.[6] Place a tag (Figure 7.5) with your name on it on opened breakers and locks which indicates that you turned off the breakers and locks. No one should remove the tag or close the breakers or locks but you. This will allow the equipment to be pulled and worked on without the fear of being shocked or burned. Personnel working around high voltage equipment should be trained and have respect for electrical current.

After work is completed on the equipment, personnel should stand clear when the equipment is energized (electrical current turned on). Make sure that the equipment is properly grounded. Personnel working with electrical equipment should have a good knowledge of electrical circuits and circuit testing. They should get clearance (approval) to work on the equipment only if they are qualified. If no one is knowledgeable about electrical circuits, the water utility should contact an electrician from a local electrical firm.

Safe procedures that must be used when working around electrical equipment include:

1. Only qualified persons can work on electrical equipment,
2. Electrical installations must be maintained in a safe condition,

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[6] *When an electrician "closes" an electrical circuit, the circuit is connected together and electricity will flow. Closing a circuit is similar to opening a valve in a pipeline. The reverse is also true. Opening an electrical circuit is similar to closing a valve on a pipeline.*

DANGER

MAN WORKING ON LINE

DO NOT CLOSE THIS SWITCH WHILE THIS TAG IS DISPLAYED

SIGNATURE ______________________

This is the ONLY person authorized to remove this tag

NOTE: Tag also should include: TIME OFF ____________
DATE ____________

Fig. 7.5 Typical warning tag
(Source: Industrial Indemnity/Industrial Underwriters Insurance Cos.)

3. Electrical equipment and wiring must be protected from mechanical damage and environmental deterioration,
4. Covers or barriers must be installed on boxes, fittings and enclosures to prevent accidental contact with live parts,
5. An acceptable service pole must be used,
6. Equipment must be suitably grounded,
7. Provisions must be made for suitable overcurrent protection,
8. Machinery must be locked out during cleaning, servicing or adjusting,
9. Machinery must be de-energized, locked or blocked to prevent movement if exposed parts are dangerous to personnel, and
10. If a switch or circuit breaker is tagged and locked out, only the person placing the tag should remove it.

"REMEMBER:"
Leave electrical repairs to the experts.

7.38 Abandoning and Plugging of Wells

Wells that are no longer useful should be abandoned and plugged for the following reasons:

1. To assure that groundwater is protected and preserved for further use,
2. To eliminate the potential physical hazard to people, and
3. To protect nearby wells from contamination.

Obtain the appropriate permits from the proper agency. Depending on the locality, this may be a local, state or federal agency. Follow the guidelines issued by the permitting agency and use experts (such as a geologist) where necessary. Review Chapter 3, Section 3.18, "Abandoning and Plugging of Wells" in *SMALL WATER SYSTEM OPERATION AND MAINTENANCE.*

7.39 Safety Inspection

Safety around wells is the responsibility of the well operator. A periodic inspection should be performed at each well site whether the well is in service or out of service. Keep a record of each monthly inspection and use the remarks column to make special notations. Some things that you should inspect for are:

1. Cleanliness of site,
2. Locks on electrical panels,
3. Condition of fencing around site, and
4. Caution/warning signs in place where necessary.

Any problems or hazards, safety or otherwise, should be corrected as soon as possible. If you cannot take care of the problem, notify your supervisor about the nature of the problem and what type of support you will need to correct the problem.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.3G What protective clothing should be worn when handling hypochlorite?

7.3H How should glassy phosphate be handled?

7.3I If no one working for a water utility is knowledgeable about electrical circuits, how can a water utility have a malfunctioning electrical system repaired?

7.3J List the items that should be included in the safety inspection of a well site.

End of Lesson 1 of 2 Lessons on SAFETY

DISCUSSION AND REVIEW QUESTIONS

Chapter 7. SAFETY

(Lesson 1 of 2 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. What is safety?
2. Who is responsible for safety?
3. What is the one objective of a safety program?
4. What are the causes of accidents?
5. How would you test a safety shower and eye/face wash?
6. What should be done before entering a confined space?
7. Why should hazardous gas detection devices be calibrated regularly?
8. How can an object be moved if it is too heavy for operators to lift?
9. Why is safety around wells important?
10. How should hydrochloric acid be transported?
11. What would you do if acid splashed in your eyes?

CHAPTER 7. SAFETY

(Lesson 2 of 2 Lessons)

7.4 PUMP SAFETY

7.40 Uses of a Pump

When we think of pumps, we commonly think of pumping water. Actually, pumps can do many things as is illustrated by the following definitions of a pump:

1. An apparatus or machine which forces liquids, air, or gas into or out of things.
2. A machine which increases the static pressure of fluids (air and water).
3. Pumping is the addition of energy to a fluid which is used mainly for the purpose of moving the fluid from one point to another.

7.41 Guards Over Moving Parts

A pump has moving parts. Where there are moving parts there is potential danger. All mechanical action or motion is hazardous, but in varying degrees. *ROTATION MEMBERS, RECIPROCATING ARMS, MOVING PARTS,* and *MESHING GEARS* are some examples of action and motion requiring protection on pumps.

Rotating, reciprocating and transverse (crosswise) motions (Figure 7.6) create hazards in two general areas:

1. At the point of operation where work is done, and
2. At the points where power or motion is being transmitted from one part of a mechanical linkage to another.

Any rotating device (pump shaft) is dangerous. Whatever is rotating can grip clothing or hair and possibly force an arm or hand into a dangerous position. While accidents due to contact with rotating objects are not frequent, the severity of injury is very high.

Whenever hazardous machine actions or motions are identified, a means for providing protection for operators is essential. Enclosed guards are used to protect operators from rotating parts on pumps. The enclosed guard prevents access to dangerous parts at all times by enclosing the hazardous operation completely. The basic requirement for an enclosed guard is that it must prevent hands, arms or any other part of an operator's body from making contact with dangerous moving parts. A good guarding system eliminates the possibility of the operator or another worker placing their hands near hazardous moving parts. Figures 7.7 and 7.8 are pictures showing examples of good, effective guarding systems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.4A What are the uses of pumps?

7.4B List the moving parts on a pump which require guards.

7.4C How can rotating devices injure you?

7.4D What is the basic requirement for an enclosed guard?

7.42 Maintenance and Repair

Pumps, as any other equipment, need preventive maintenance and periodic repair. A proper maintenance program will allow you to obtain satisfactory service from your pumps and minimize any potential safety hazards.

Remember your routine inspections will help you prolong the life of your pump and other equipment. Figure 7.9 identifies "danger" areas on pumps. These "danger" areas could be safety hazards to operators or areas where the pump could fail.

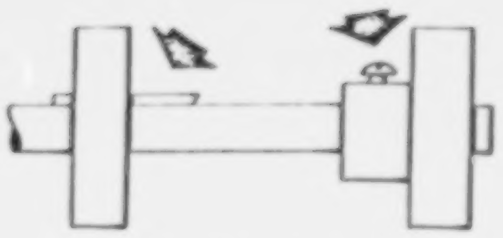
CAUTION

Do not operate a pump against a closed discharge valve, otherwise overheating will occur.

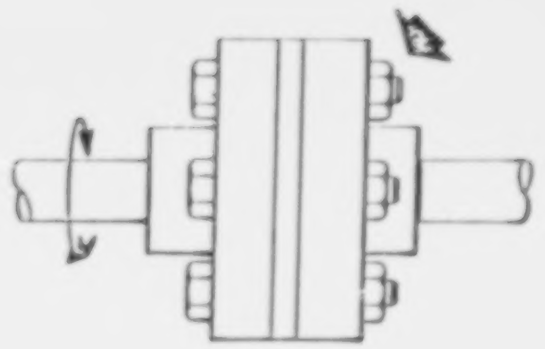
Whenever maintenance is to be performed on pumps or any other equipment, the work must be carefully planned and coordinated with other operators and the operation of the facilities. Good planning includes figuring out how to do the job from start to finish. Planning includes identifying potential safety hazards *BEFORE* starting a job and deciding how they can be avoided. To do a job safely, use the proper tools and equipment and *ISOLATE THE PUMP AND/OR EQUIPMENT FROM THE POWER SOURCE.*

Isolate power by throwing the appropriate switches and circuit breakers, locking them out, and tagging the locks with your name on the tag. The tag must be clearly visible. Only the person who signed the tag can turn the power back on. Power can also be isolated by unplugging the pump or equipment. *ALWAYS ISOLATE THE POWER BEFORE BEGINNING ANY MAINTENANCE.*

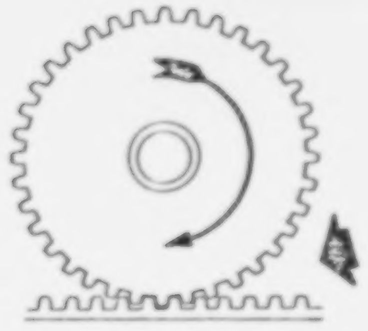
Safety coordination and planning requires that supervisory personnel and all other potentially involved or affected personnel be notified and necessary approvals obtained *BEFORE* starting any maintenance work. This means that any other people who operate the equipment must be notified. If the electricity must be shut off to do any work or maintenance, all persons affected by the lack of power also must be notified. A good safety practice is to have other persons leave the work area until the job is completed so no one will accidentally turn on the power or equipment. When maintenance personnel must leave a job site for any reason, on returning they must check and be sure that the circuit is still locked out *BEFORE* resuming maintenance on the equipment.



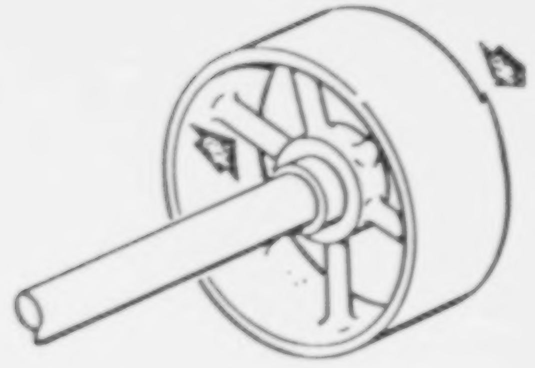
Rotating shaft and pulleys with projecting key and set screw



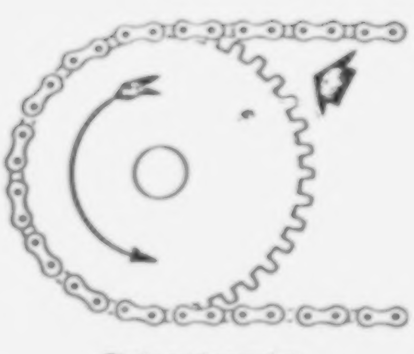
Rotating coupling with projecting bolt heads



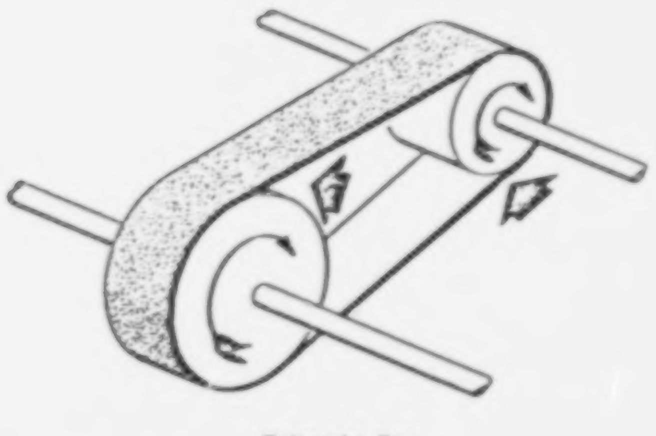
Rack and gear



Rotating pulley with spokes and projecting burr on face of pulley



Chain and sprocket



Belt and pulley

NOTE: Short, thick arrows indicate danger points

Fig. 7.6 Examples of typical rotating, reciprocating, and transverse mechanisms

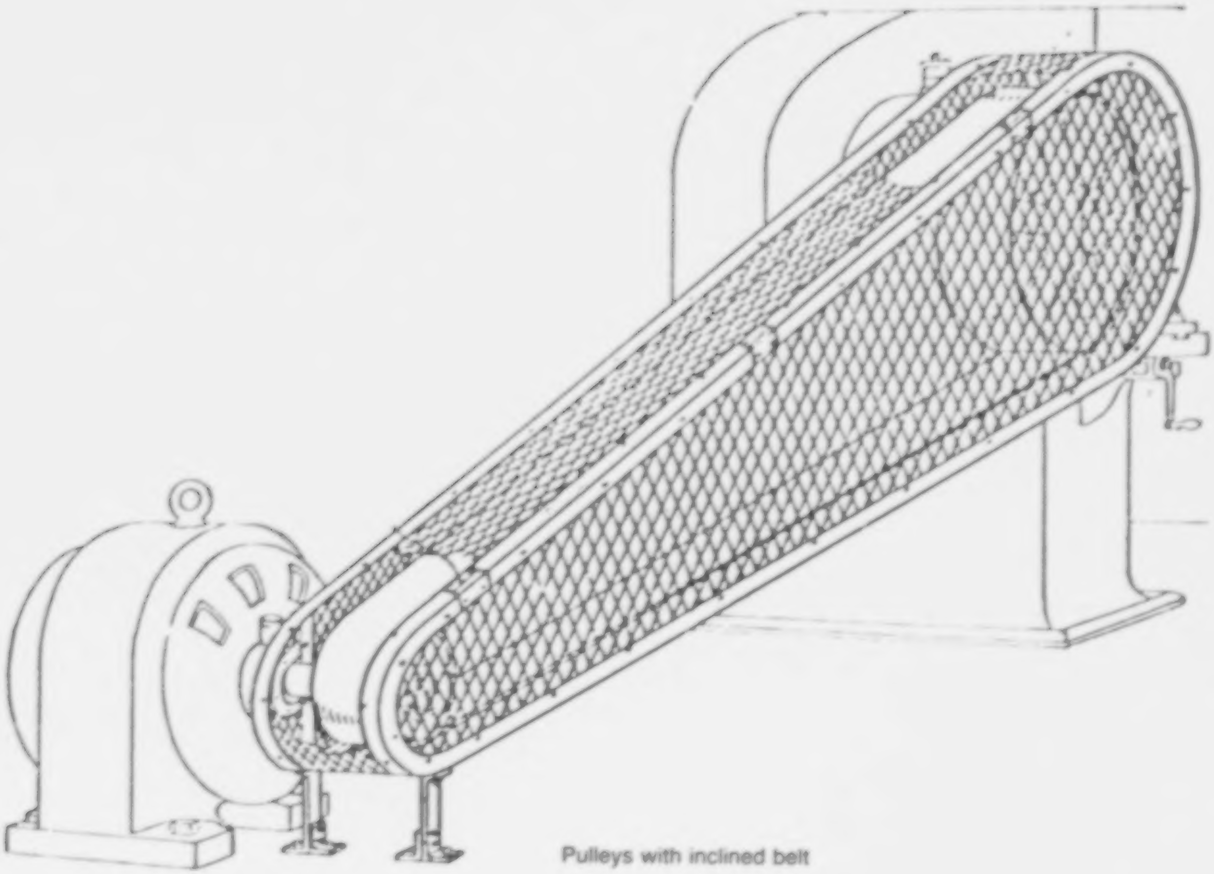
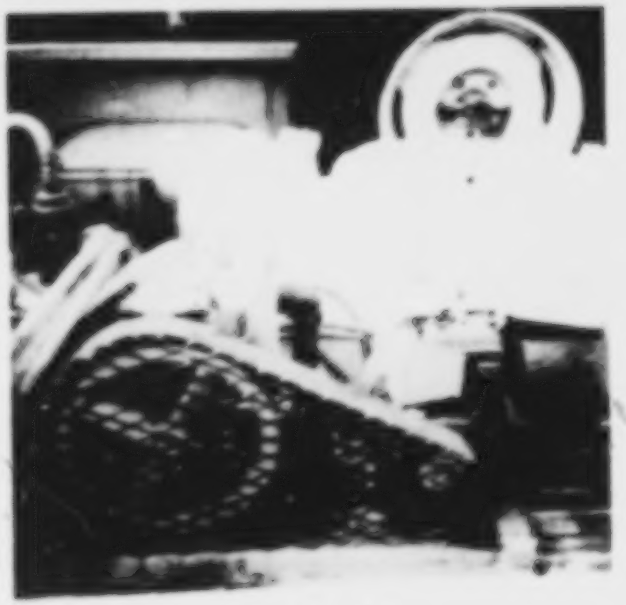
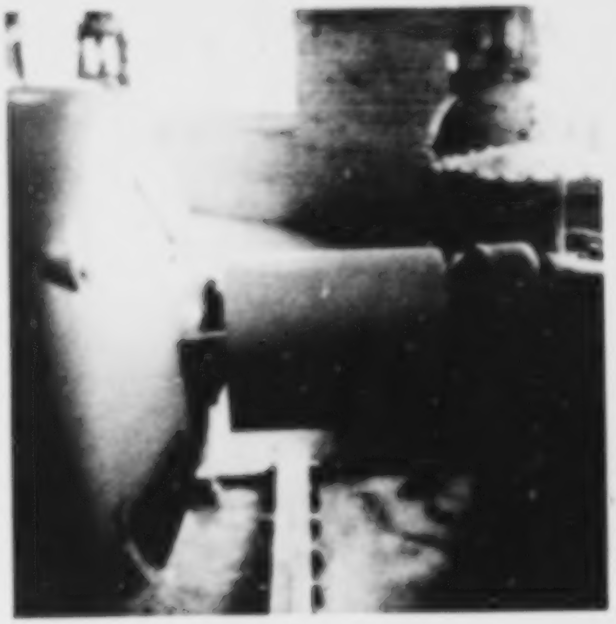

Pulleys with inclined belt

Fig. 7.7 Enclosed guard protecting operators from moving pulleys and belt



Guard over belt on gas engine

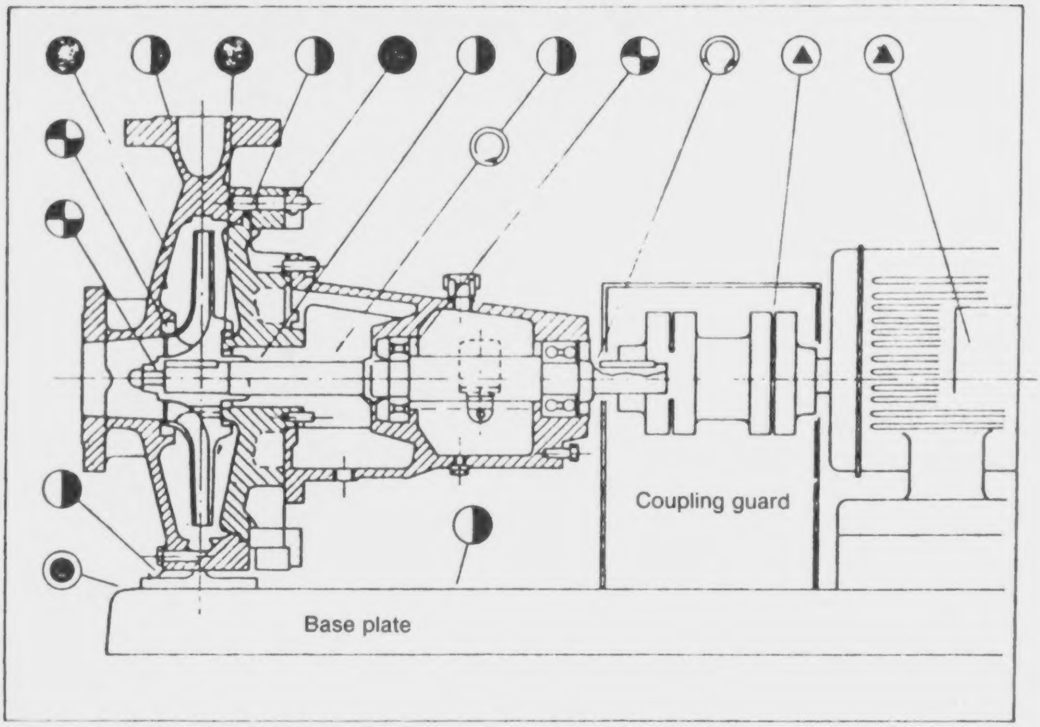


Guard over coupling

Guard on gas engine and pump

Guard on hypochlorinator

Fig. 7.8 Effective guarding systems



● Fracture can cause leakage and mechanical damage and injury to personnel.

◓ Leakage and possibility of collection of leakage (vaporizing).

◕ Seizure of parts or other mechanical failure

○ Rotating parts area needs protection and care

◉ Lifting facility

▲ Electric protection and or sparks possibility

Fig. 7.9 "Danger" areas on pumps

If, or when, the electrical circuit must be turned back on, all persons in the area must be notified that the current is going to be turned back on again.

When equipment may be operated by a standby or backup power source, this power source must also be isolated so the equipment cannot be energized. When emergency standby engines and pumps must be maintained that are started by a battery, the battery must be disconnected and the fuel source shut off. Appropriate warning signs and tags must be posted where they are visible indicating that the power source is disconnected.

ALWAYS ISOLATE EQUIPMENT FROM THE DRIVING SOURCE BEFORE STARTING ANY WORK.

If a stationary pump or motor must be moved, use a lifting sling. Attach the sling properly to the equipment and lift the equipment up off the base. Set the pump or motor down on a cart or pallet and transfer the pump or motor to a work shop for repair or another location as necessary.

NEVER LEAVE ANY EQUIPMENT HANGING FROM A SLING IN MID-AIR. NEVER WORK ON EQUIPMENT WHEN IT IS HANGING FROM A SLING. ALWAYS LOWER EQUIPMENT TO THE FLOOR, SET IT ON A CART, OR PLACE IT ON A WORK BENCH BEFORE STARTING MAINTENANCE.

When transferring pumps or equipment from one location to another, use a sturdy cart, truck or transfer the equipment on a pallet by using a fork lift. Many operators have seriously injured their backs attempting to lift and carry heavy pumps, motors and other equipment.

7.43 Storage of Lubricants and Fuel

Lubricants and fuels must be stored in a separate facility from other storage areas because of the potential fire hazard. Clean up all spills immediately and keep the area neat and clean. A fire extinguisher must be readily available near the storage facility, but never inside the facility.

QUESTIONS

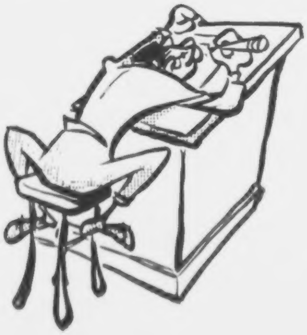
Write your answers in a notebook and then compare your answers with those on page 389.

7.4E What should be done before beginning maintenance on a pump?

7.4F What is safety planning and coordination?

7.4G Why should you never work on equipment hanging from a sling in mid-air?

7.4H Why should lubricants and fuels be stored in a separate facility from other storage areas?



7.5 WORKING IN STREETS

7.50 Definition of Terms

Before we discuss how to work safely in streets, let's review some of the terms we'll use.

WORK SITE — general place where a construction or maintenance operation is taking place.

WORK SPACE — space set apart which is identified for use by workers and equipment performing work which is protected, marked, or signed to exclude vehicular and pedestrian traffic.

TRAFFIC CONTROL — the process of advising motorists and pedestrians as to detailed requirements or conditions affecting road use at specific places and times in order that proper action may be taken and accidents or delays avoided.

Work site traffic control applies to maintenance and construction activities or other special temporary conditions affecting road use at specific places and times.

TRAFFIC CONTROL DEVICE — all signs, signals, markings and devices placed on or adjacent to a street or highway by a public body or official having jurisdiction to regulate, warn, or guide traffic. Traffic Control Devices are used to slow and guide traffic and to warn motorists of changes or possible changes in conditions.

TRAFFIC CONTROL ZONE — the entire area of the roadway which encompasses all traffic control devices used to warn, regulate or guide drivers through or around a work site.

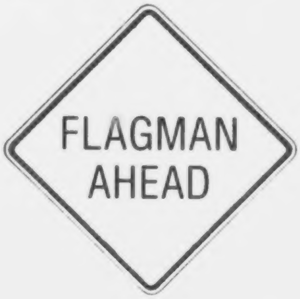
ROADWAY CLOSURE — the taking of some portion of the roadway for the exclusive use of workers, materials, or equipment during a construction or maintenance operation. Traffic is excluded from the closed portion and must use the remaining portion of the roadway if any exists. The option exists to close a portion of a lane or one or more travel lanes.

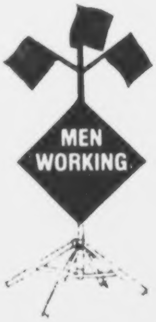
7.51 Work Area Protection

All work done in streets and highways must be performed in accordance with city, local and state regulations regarding work in roadways. In many locations a roadway encroachment permit must be obtained *BEFORE* starting work.

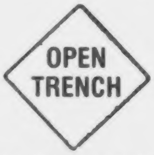
Most work area accidents on streets and highways can be attributed to the lack of proper advance warning, signing and guidance. Speed of traffic and the increased maintenance of utility lines under our streets have created hazards for the motorists. We must channel traffic flow through a work area safely with the following items considered.

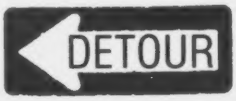
1. PREWARN
   Give the motorist time to THINK and REACT to avoid construction hazards.



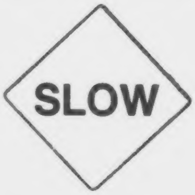


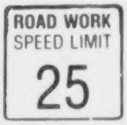
2. SIGN PROPERLY
   Use the standard shapes, sizes and colors designated by your state highway or transportation agency.



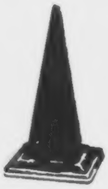


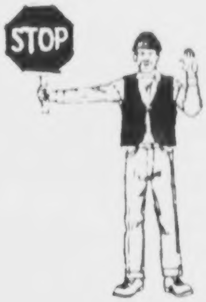
3. REGULATE SPEED
   The motorists' speed must be controlled so they may proceed safely through the construction area with a minimum of inconvenience.





4. GUIDE PROPERLY
   The driver must be directed through the work area by clearly indicated instructions and traffic devices (traffic cones).





The person installing these devices should drive through the area as another motorist would. This is a final check to determine if the work area protection system is actually effective.

7.52 Setting Up Equipment in Streets

The most common cause of worker fatality is an accident involving moving vehicles. Personnel of a water utility are exposed to this potential hazard because of work necessary to install, repair and/or operate valves in the street. Operators must work in manholes, open trenches, regulation vaults and on roadway shoulders. Any type of work in the street, roadways, or within a highway right-of-way increases the potential for hazard not only because of the nature of the job, but is also complicated because of the added problems of motorists and pedestrians.

Each job has its particular hazard which should be reviewed in a *TAILGATE SAFETY MEETING.*[7] All aspects of the job should be reviewed and someone should be responsible for each particular part of the job in order to make the job safe.

To make a job safe in the street will require:

1. Good planning,
2. Adherence to safety standards,
3. Adequate supervision, and
4. Frequent inspection.

Traffic control systems are used on street work sites to protect the:

1. Work force,
2. Motorist,
3. Pedestrian,
4. Equipment, and
5. The facility.

Traffic control procedures are used at work sites to:

1. Warn motorists and pedestrians of hazards involved and to advise them of the proper manner to travel through the area,
2. Inform the drivers of changes in regulations or additional regulations that apply to traffic through the area,
3. Guide traffic through and around the work site, and
4. Identify areas where traffic should not operate.

Whenever workers (personnel working on the street) are exposed to vehicular traffic, they should wear in addition to their normal clothing, a high visibility shirt, poncho, vest or coat. This clothing should be colored red or safety orange. A safety hat (hard hat) should be worn whenever you are near traffic.

Some jobs will require a flagman to help control the work space. Flagmen are required where:

1. Workmen or equipment intermittently block a traffic lane;
2. One lane must be used for two directions of traffic (a flagman is required for each direction of traffic); and
3. The safety of the public and/or workmen requires it.

All flagmen must wear an orange jacket or vest for daytime use and a reflectorized belt and suspender harness for use at night. During the day, flagmen use a double-sided sign paddle with "Slow" printed on one side and "Stop" on the other. At night a flashlight with red lens is used.

The flagmen should be positioned at least 100 feet (30 m) in front of the work space and a sign reading "Flagman Ahead" should be placed as far ahead of the flagmen as practical (500 feet or 150 meter minimum). Figure 7.10 shows flagmen and hand signaling motions and devices. Flagmen are expected to regulate and control the flow of traffic in a safe and orderly fashion. Flagmen and utilities have been sued because improper actions by flagmen caused an accident.

Effective placement of signs and barricades can make work sites in streets safe places to work. You must follow local safety regulations regarding the locations and types of signs to protect your agency from lawsuits if an accident occurs. However, you should study each work site and make any necessary improvements to insure a safe area to work.

The following pictures and descriptions will give you some ideas on how to establish safe work sites.

Barricades are placed in a manner to give ample warning to drivers who are planning a right turn. Traffic inconvenience is minimized. Employees are protected while working in a difficult location.

---

[7] *Tailgate Safety Meeting. The term TAILGATE comes from the safety meetings regularly held by the construction industry around the tailgate of a truck.*

TO *SLOW* DAYTIME TRAFFIC

To Slow Traffic
(Short up and down motion
with extended right hand.)

TO *STOP* DAYTIME TRAFFIC

To Stop Traffic
("Stop" paddle high enough
to be above garment.)

TRAFFIC PROCEED

Traffic Proceed
(Never use a flag or paddle
as a signal to move traffic.)

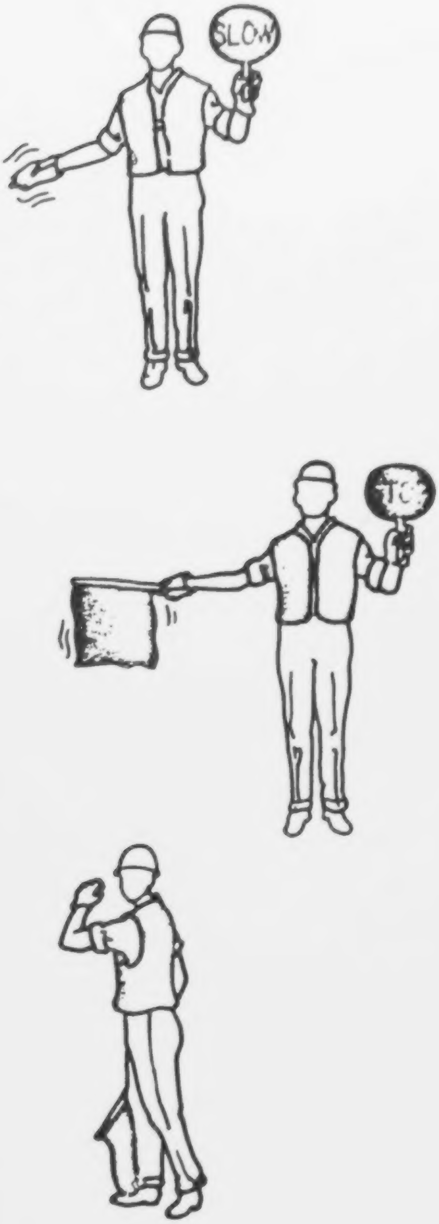


Fig 7.10 Flagmen and hand signaling motions and devices

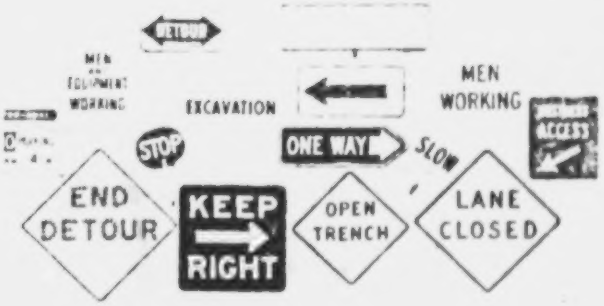
This work area on a busy thoroughfare required considerable planning to achieve free movement of vehicles past the area. Two lanes are provided in the direction of heaviest daytime traffic flow.

MORE WATER
FOR FAST GROWING
LOS ANGELES
YOUR COOPERATION
IN THIS NECESSARY CONSTRUCTION
IS APPRECIATED
DEPARTMENT OF
WATER AND
POWER
LOS ANGELES CITY OWNED

This sign, though not strictly a work area protection device, helps promote customer acceptance and understanding of the necessity for important construction work.

A work area of considerable length on a major metropolitan artery. All trucks and equipment are contained within the area. Barricades serve dual purpose by warning motorists and also giving employees an audible warning in the event a vehicle crashes into the work area.

Job site located in the number two lane of a six lane boulevard. Directional signs channel traffic smoothly around the work area.


DETOUR
MEN
OR
EQUIPMENT
WORKING
EXCAVATION
MEN
WORKING
ACCESS
STOP
ONE WAY
SLOW
END
DETOUR
KEEP
RIGHT
OPEN
TRENCH
LANE
CLOSED

Many construction signs are available to help direct motorists and pedestrians through construction areas with a minimum of inconvenience.

Suggested distances for the spacing of delineators (traffic cones) and warning devices or signs are summarized in Table 7.4.

TABLE 7.4 SUGGESTED DISTANCES FOR WARNING DEVICES[a]

TRAFFIC CONES

MPH	Distance in Feet
Up to 30 mph	10-20 feet
30 to 40 mph	25-35 feet
45 to 55 mph	40-50 feet

HIGH LEVEL WARNING DEVICE PLACEMENT GUIDES

MPH	Distance in Feet
25 mph or below	150 feet
35 mph	250 feet
45 mph	500 feet
55 mph	750 feet

[a] Contact your state highway department or transportation agency for your regulations.

The following figures are some typical setups for working in the street (Figures 7.11, 7.12 and 7.13).

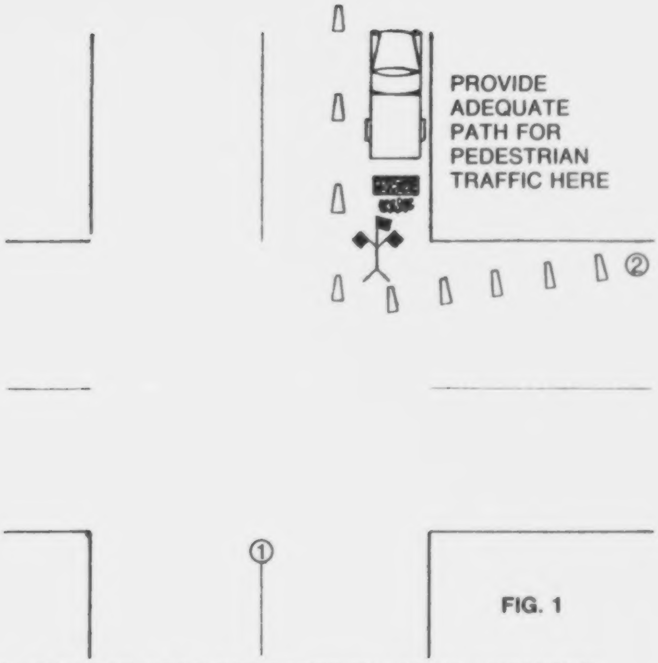

PROVIDE
ADEQUATE
PATH FOR
PEDESTRIAN
TRAFFIC HERE
②
①

FIG. 1

PLACEMENT NEAR INTERSECTION. SOME LOCATONS MAY REQUIRE HIGH LEVEL WARNINGS AT POINTS ① ②

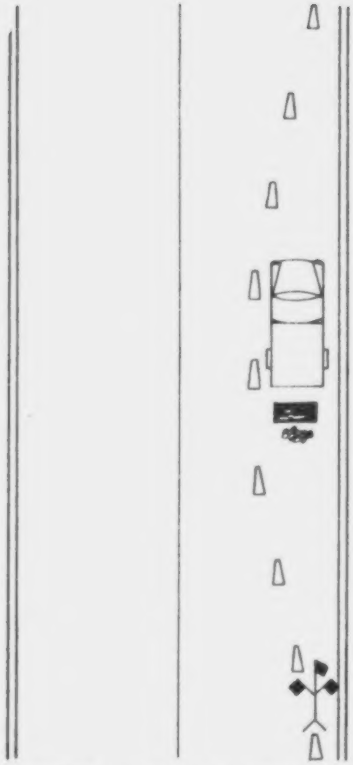


FIG. II

NORMAL SERVICE, LEAK OR CONSTRUCTION PLACEMENT. SEE TABLE 10.4 FOR DISTANCES.

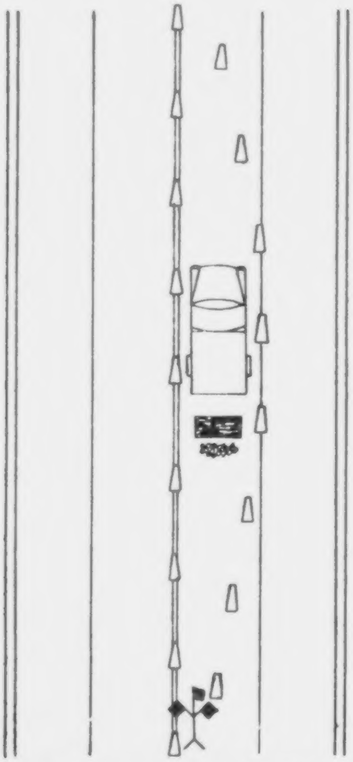


FIG. III

MULTI-LANE HIGHWAY PLACEMENT. PLACE HI-LEVEL WARNING IN SAME LANE AS OBSTRUCTION. SEE TABLE 10.4 FOR DISTANCES.

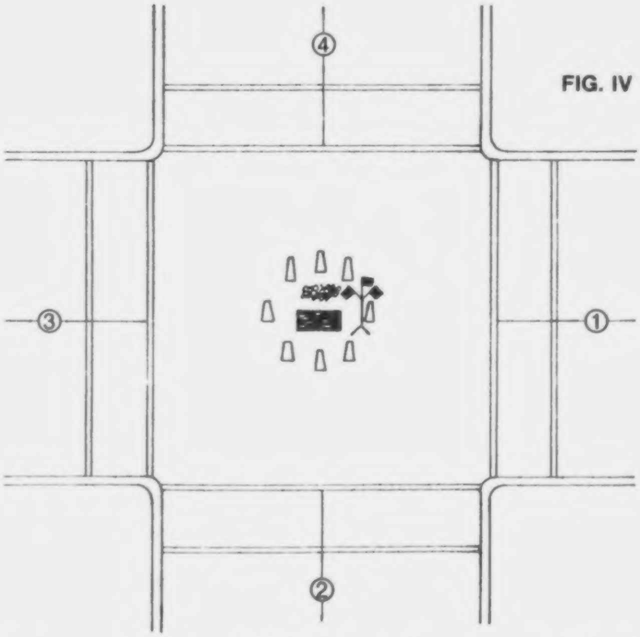


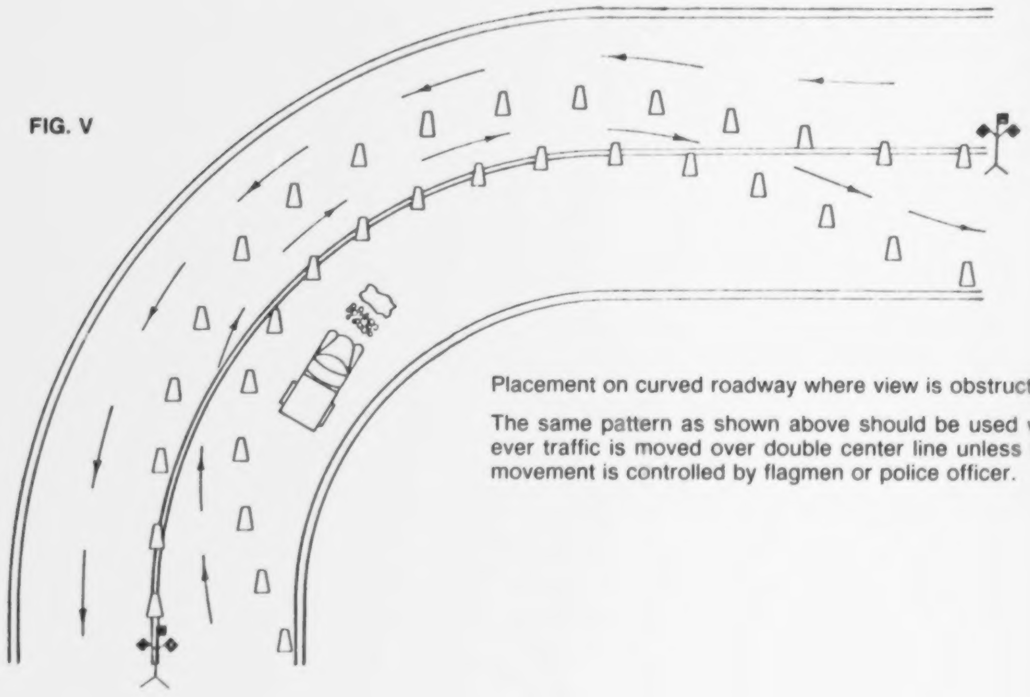
FIG. IV

PLACEMENT AT MAJOR TRAFFIC SIGNAL CONTROLLED INTERSECTION WHERE CONGESTION IS EXTREME. SOME LOCATIONS MAY PERMIT WARNINGS AT POINTS *1 2 3 4.*

Fig. 7.11 Placement of traffic cones and signs

TYPICAL HIGH-LEVEL WARNING

FIG. V



Placement on curved roadway where view is obstructed.

The same pattern as shown above should be used whenever traffic is moved over double center line unless traffic movement is controlled by flagmen or police officer.

FIG. VI

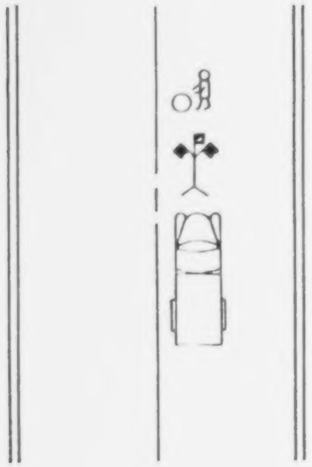
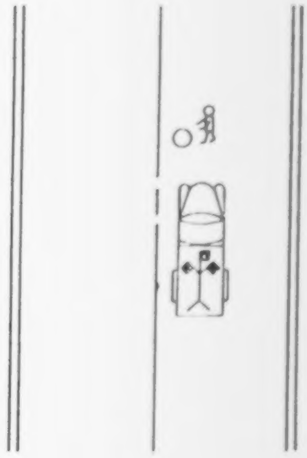


FIG. VII



Placement for gate operation or other jobs of short duration. Employee must wear high visibility red jacket.

Alternate method for operation described at left. High-level warning is mounted on rear of vehicle that is parked in advance of work location. Employee must wear high visibility red jacket.

Fig. 7.11 Placement of traffic cones and signs (continued)

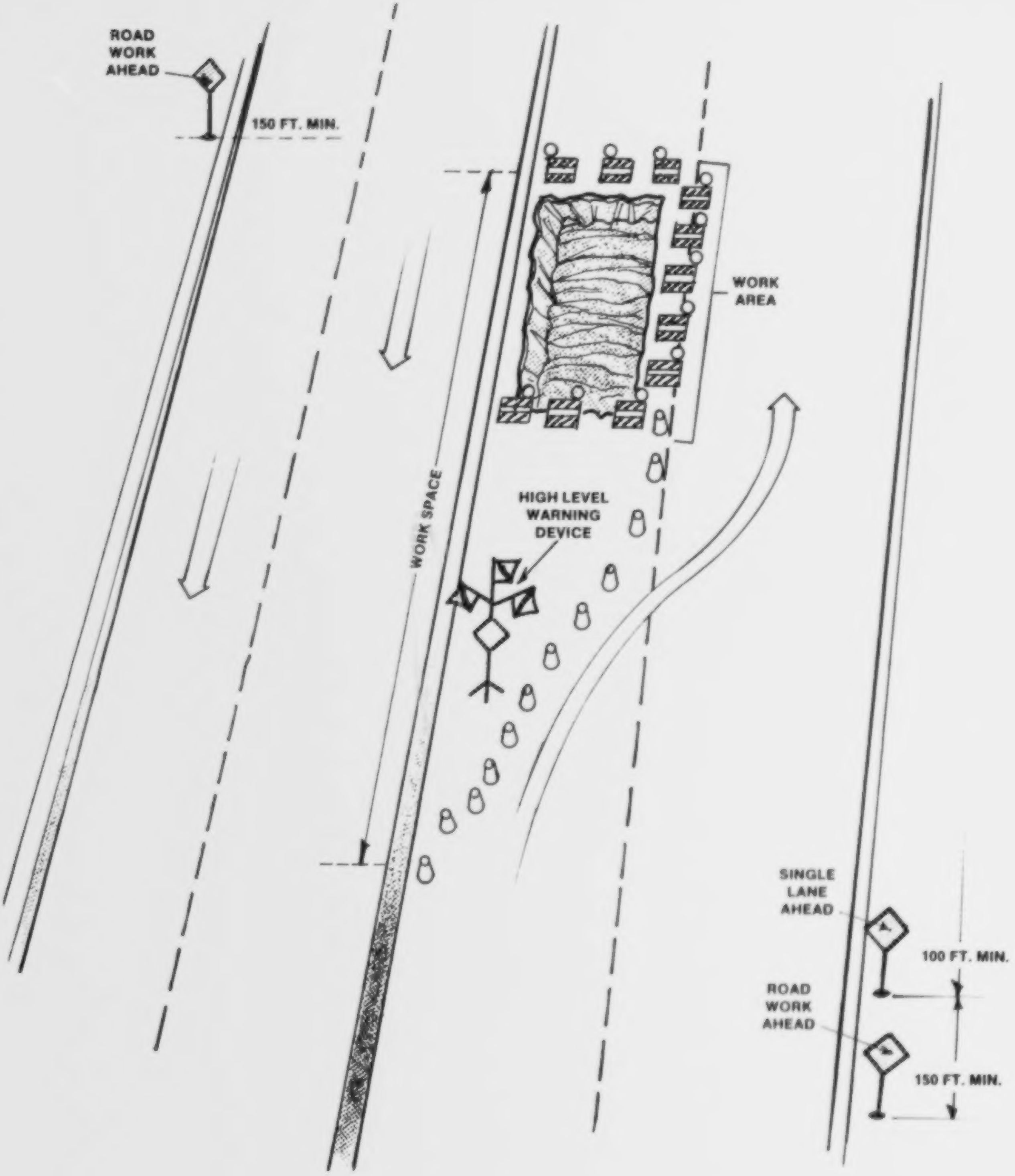

ROAD
WORK
AHEAD
150 FT. MIN.
WORK
AREA
WORK SPACE
HIGH LEVEL
WARNING
DEVICE
SINGLE
LANE
AHEAD
100 FT. MIN.
ROAD
WORK
AHEAD
150 FT. MIN.

Fig. 7.12 Closing of left lane

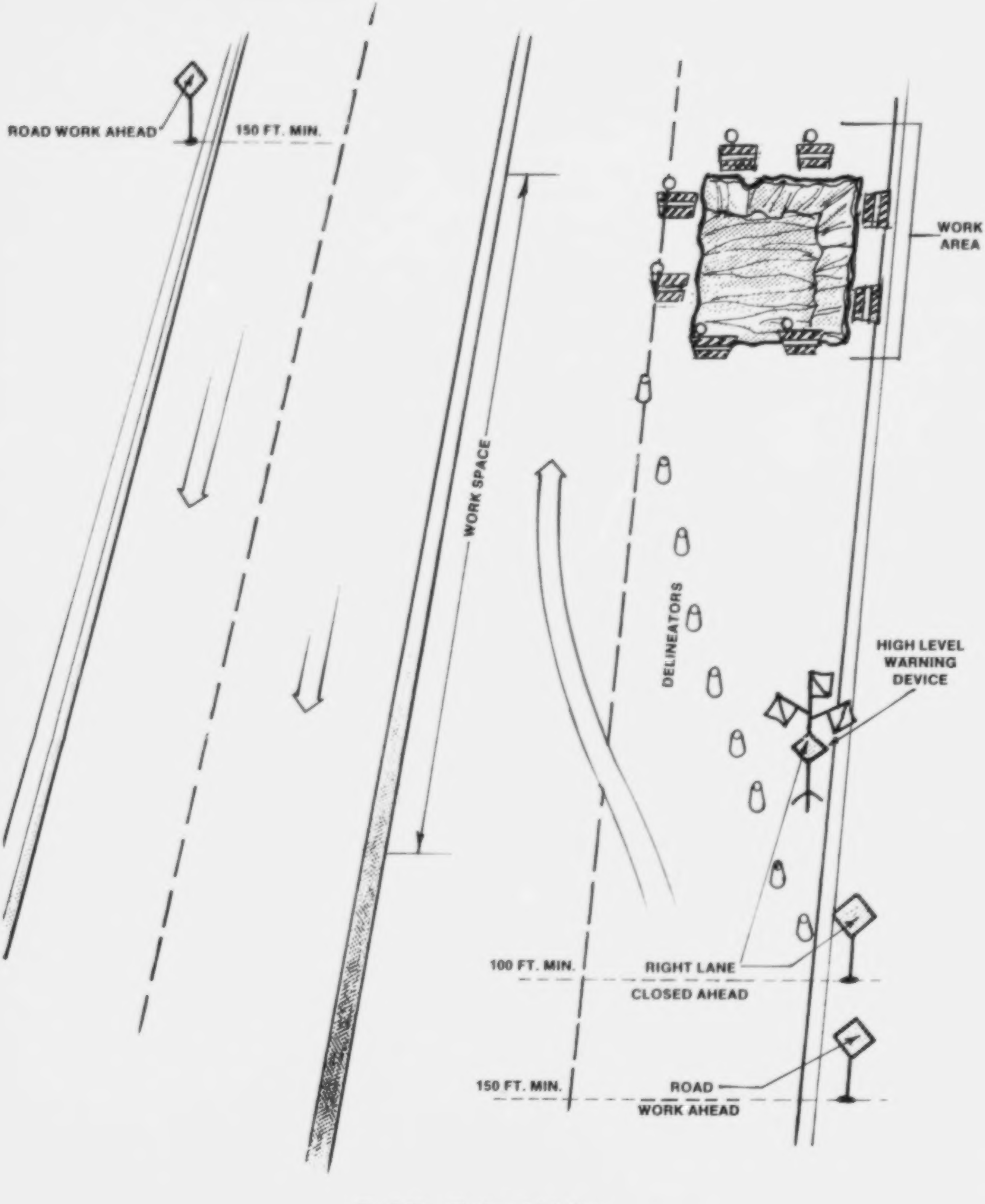

ROAD WORK AHEAD
150 FT. MIN.
WORK SPACE
WORK AREA
DELINEATORS
HIGH LEVEL WARNING DEVICE
100 FT. MIN.
RIGHT LANE CLOSED AHEAD
150 FT. MIN.
ROAD WORK AHEAD

Fig. 7.13 Closing of right lane

Accidents associated with work on the street are a prime indicator of a breakdown in the traffic control system. Any accident that occurs at the work site should be analyzed to determine whether adjustments to the traffic control zone are needed. The time you spend to properly protect the work space with traffic controls may save your life. Figure 10.14 illustrates some good practices in work area protection.

7.53 Tailgate Topic on Street Warning Devices

Each job in a roadway presents problems in methods of giving motorists adequate warning of our presence. Whenever there are new mains to be laid, mains repaired, or mains relocated because of freeway construction, you may be required to work in traffic. All this construction has a bad effect on the motorist in one respect; drivers pay less attention to work going on in the street, and they do not slow down in many cases where they pass our jobs.

HE SAID SLOW, TURKEY!!
SLOW

Our only protection is to give the motorist sufficient warning by use of barricades, cones and flagmen. Placement of signs requires careful thought. Some job locations can present real problems when insuring safety for all concerned. We all know most of the established rules for placing warning devices. A review of some of these rules may remind us of a few points we forget to consider.

1. Whenever possible, use a flagman when setting up or breaking down the work area.
2. Use more, rather than too little, warning equipment at the work area.
3. Anticipate the unexpected and irrational acts of pedestrians and vehicles.
4. Do not use the same setups on streets with fast moving traffic as would be used on slow traffic streets.
5. Keep all tools and materials within the confines of the protected work area.

These are just a few points to consider. Every job is different. Use good safety judgment and past experience as a guide. Remember, we not only want to set up the job so we are obeying the law, we want to go even further and set up so an accident can't happen.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.5A What items should be considered when channeling traffic flow through a work area?

7.5B What should persons who must work on streets wear?

7.5C List the hand signaling motions commonly used by flagmen.

7.5D List the rules that should be considered when setting up street warning devices.

7.54 Excavations[8]

7.540 Safety Rules for Excavations

Excavations are necessary to install or repair water lines in streets or roadways. Regulations and requirements governing excavations may be found in your state construction safety orders or other similar documents. A permit may be required for any excavations four feet (1.2 meters) or more in depth in which personnel must work. Shoring is also required.

General safety rules include:

1. Employer must inspect any excavation for hazards from possible moving ground before employees may work in or adjacent to the excavation.
2. Excavations must be inspected by qualified persons after each rain storm, earthquake or other hazard.
3. Large excavations must be inspected daily.
4. Properly qualified supervisors must be on site at all times during excavations.
5. Safety provisions must be taken to protect workers installing or removing shoring systems.
6. Spoil (material removed from excavation) must be kept back at least four feet (1.2 m) from the edge of all excavations.
7. Safe and convenient access to an excavation must be provided.
8. Effective barriers must be installed at excavations adjacent to mobile equipment.
9. Water must not be allowed to accumulate in any excavation.

7.541 Trenches

A trench is an excavation in which the average depth exceeds the width and the width is 15 feet (4.5 meters) or less at the bottom. The same general requirements which apply to excavations apply to trenches. Trenching is more common than excavations in water utility work. Exits must be provided at 25-foot (7.4-meter) intervals for all occupied trenches four or more feet (1.2 m) deep.

Covers placed over trenches in roadways must be secured against displacement. Covers are usually placed over a trench at the end of the day. This provides for opening of the street for peak traffic flow. Occasionally excavations or trenches must cross sidewalks or other pedestrian rights of way. When this is necessary, a safe, temporary right of way must be provided or foot traffic should be rerouted.

Figure 7.15 illustrates various types of trench shoring conditions.

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[8] *Also see Chapter 3, Distribution System Facilities, Section 3.653, "Excavation and Shoring."*

1. Truck and spoil bank placed ahead of excavation to provide employee protection.
2. Cone pattern arranged with gentle curves — traffic adjusts smoothly.
3. Pipe blocked to prevent rolling into street. Barricades provide pedestrian warning.
4. Material neatly stacked.
5. High level warning or barricades of solid material to give audible warning of vehicles entering work area.
6. Pedestrian bridge over excavation.
7. Left side of truck protected by cone pattern, work area entirely outlined.
8. Tools out of way of pedestrians, tools not in use replaced in truck.
9. Pickup parked in work area or on street away from work area.

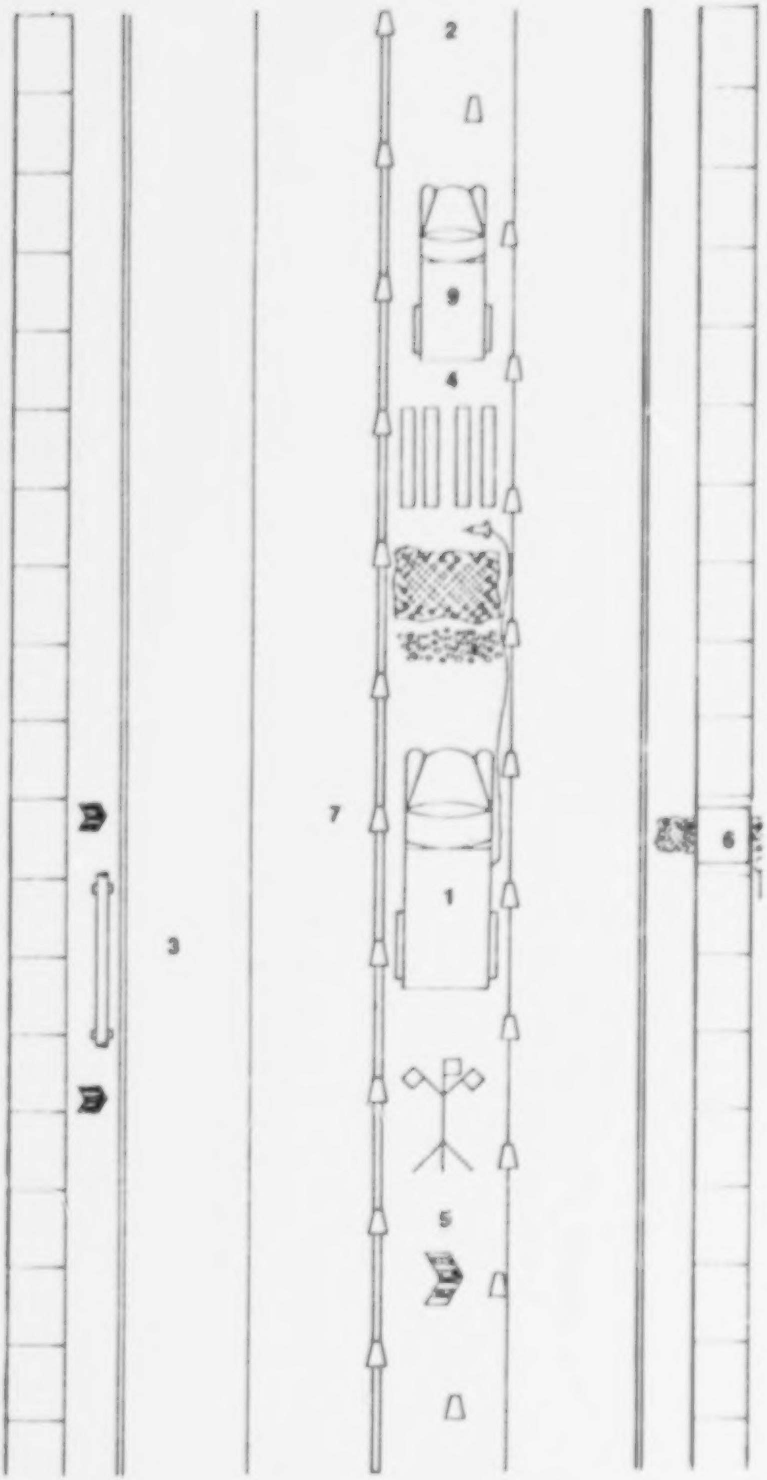


Fig. 7.14 Good practices in work area protection

RUNNING MATERIAL

Sheet Piling or equivalent solid sheeting is required for trenches four feet or more deep.

Longitudinal-stringer dimensions depend upon the strut braces, the stringer spacing, and the depth of stringer below the ground surface.

Greater loads are encountered as the depth increases, so more or stronger stringers and struts are required near the trench bottom.

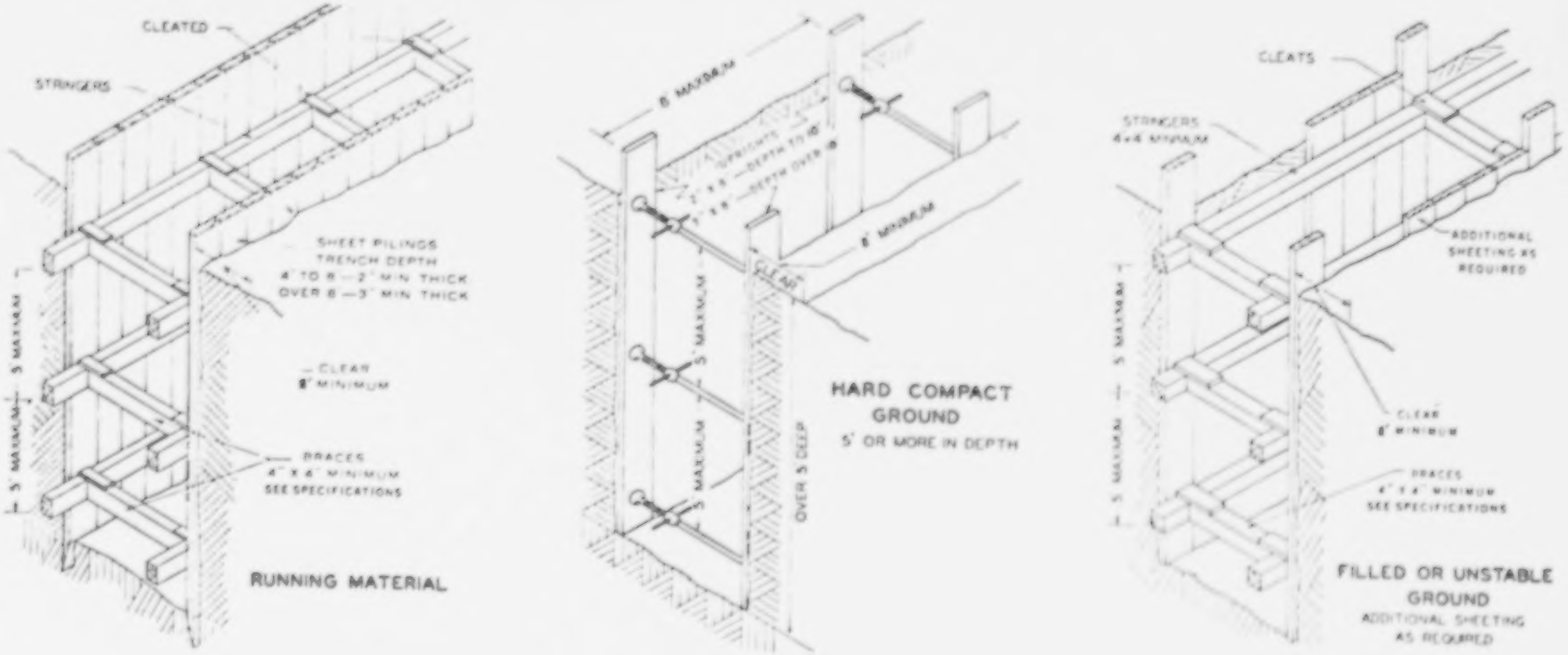
HARD COMPACT GROUND

Trenches 5 feet or more deep and over 8 feet long must be braced at intervals of 8 feet or less.

SATURATED, FILLED OR UNSTABLE GROUND

Sheeting must be provided, and must be sufficient to hold the material in place.

Longitudinal-stringer dimensions depend upon the strut and stringer spacing and upon the degree of instability encountered.


CLEATED
STRINGERS
SHEET PILINGS
TRENCH DEPTH
4' TO 8' — 2" MIN THICK
OVER 8' — 3" MIN THICK
CLEAR
8' MINIMUM
BRACES
4" X 4" MINIMUM
SEE SPECIFICATIONS
5' MAXIMUM
5' MAXIMUM
8' MAXIMUM
UPRIGHTS
2" X 6" — DEPTH TO 10'
3" X 8" — DEPTH OVER 10'
8' MINIMUM
CLEAR
5' MAXIMUM
5' MAXIMUM
OVER 5' DEEP
CLEATS
STRINGERS
4×4 MINIMUM
ADDITIONAL
SHEETING AS
REQUIRED
CLEAR
8' MINIMUM
BRACES
4" X 4" MINIMUM
SEE SPECIFICATIONS
5' MAXIMUM
5' MAXIMUM

RUNNING MATERIAL

HARD COMPACT GROUND
5' OR MORE IN DEPTH

FILLED OR UNSTABLE GROUND
ADDITIONAL SHEETING AS REQUIRED

Fig. 7.15 Various types of trench shoring conditions

7.542 Cave-Ins

Improper shoring can contribute to cave-ins. Many cave-ins can be avoided by using the proper shoring where warranted by soil type and condition. Also, proper shoring procedures can avoid the embarrassing situations of finding oneself in a position of helplessness while installing the bottom brace or screw jack first simply because it is the path of least resistance. That is the easy way, but not the safe way.

Another hazard is the excavated spoil bank. Usually the spoil bank is set back far enough to prevent the material from falling back into the trench and also far enough to provide a walkway or tool-rest for shovels and crowbars. Of great significance, however, is the fact that the proper setback of the spoil bank will keep the weight away from the edge of the trench. If the spoil is too heavy and too close to the edge, the wall of the trench could cave in on top of you.

The following procedures are recommended in order to prevent violations of the safety rules, to prevent cave-ins, and to help keep us from getting hurt.

1. In excavations five feet (1.5 meters) or deeper (four feet in some regulations), shoring is required and the spoil bank is to be kept back a minimum of two feet (0.6 meters) from the edge of the trench. Increase this distance consistent with the type and condition of the soil.
2. When installing braces or screw jacks, start with the top one first and progressively work downward. Removal is in reverse order, starting with the bottom brace and working upward.
3. Eight feet (2.4 meters) is the maximum spacing of uprights under the ideal conditions of hard, compact soil excavated to a depth not exceeding ten feet (3 meters). Spacing of the uprights shall be decreased and solid sheathing may be required when the depth exceeds ten feet (3 meters) or if unstable soil is encountered.
4. When sources of external vibration (trucks, railroads) are nearby, special safety precautions may be necessary. Additional bracing or other effective means are recommended.
5. In trenches four feet (1.2 meters) or deeper, ladders or ramps should be provided for access and should be located so that workers need not move farther than 25 feet (7.5 meters). The ladders should extend a minimum of 30 inches (75 cm) above the top of the excavations.

Field inspections and injury reports have indicated that the items listed above are frequently overlooked. Attention to these items is necessary if we are to reduce accidents in this area. If we continue to ignore safety regulations, the pain and suffering of accidents will continue.

The economic impact of shoring requirements is a known factor. Provision of the proper materials, equipment and the time to install and remove the shoring is a required expense. The installation of a substandard shoring system is just as expensive as one properly installed. Given the alternative, it makes sense to install the shoring system properly!

These requirements are minimal and, on occasion, the shoring and methods may have to be improved. In large excavations or where complex shoring systems deviate from regular shoring procedures, alternate shoring systems must be designed by a registered civil engineer and submitted to the appropriate authorities for approval.

7.543 Ladders

Ladders must be placed in excavations so that any worker is never more than 25 feet (7.5 meters) from the ladder. For example, one ladder is required for each 50 feet (15 meters) of trench if the ladder is placed in the center of the trench. If the ladder is placed near one end of the trench two ladders would be required. The ladders must extend 2½ feet (75 centimeters) above the surface of the excavation. Ladders are required in all excavations where a problem exists in entering or exiting the excavation. All ladders must be kept clean and in good repair.

7.544 WARNING: Look Out for Other Underground Utilities

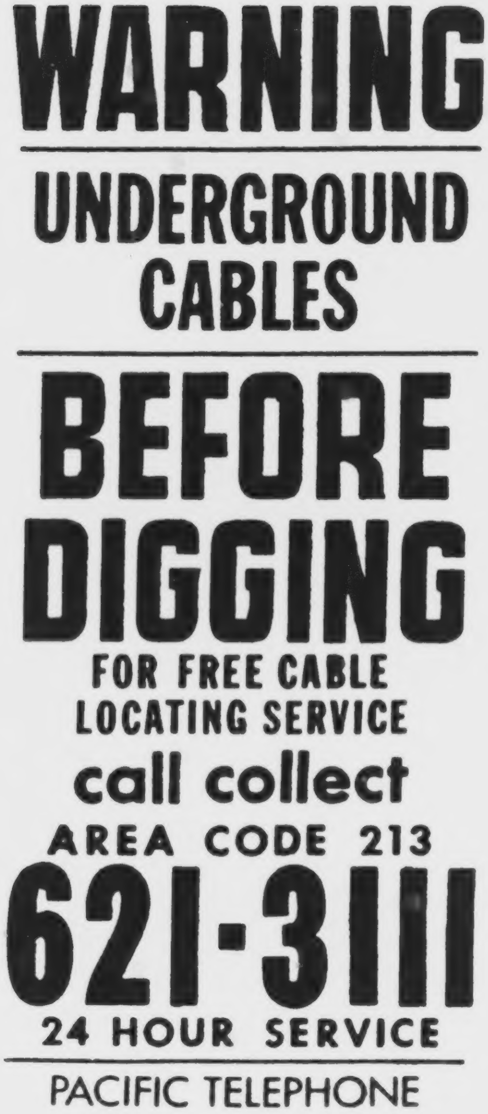
Before you do any excavating, determine the location of underground utilities and advise the utility owners of the proposed work. Some underground installations that could be damaged by excavations include underground cables, electrical services, gas mains and occasionally storm water and sewer lines that may be adjacent to proposed excavations. *NEVER* disturb a thrust block supporting an underground utility. Many phone books list an "Underground Service Alert" or "One-Call" phone number which you should call *BEFORE* you do any underground digging or drilling. Figures 7.16 and 7.17 give some typical telephone company warnings and indicators of underground cable lines.

7.55 Protect the Public

When the work area crosses the sidewalks, walkways or crosswalk areas, special consideration must be given to pedestrian safety. Every effort must be made to separate the pedestrian from the work area. Protective barricades, fencing, handrails and bridges must be used with warning devices and signs to direct foot traffic to areas where pedestrians may pass safely. Walkways in construction areas should be at least four feet (1.2 meters) wide and free of abrupt changes in grade. Where traffic must change grade, an incline should be used. Special consideration should be given to the blind and handicapped. There should be a minimum vertical clearance of seven feet (2.1 meters) and illumination should be provided during hours of darkness. Occasionally, a walkway must be closed completely. When this is necessary, foot traffic should be diverted at the closest crosswalks with the appropriate signs and barricades (Figure 7.18).

When welding is necessary on the job, suitable screens must be placed to protect the public from arc welding flash or sparks from cutting operations.

When equipment is stored on the job site, such as pipe, it should be securely blocked so it cannot be displaced.


WARNING
UNDERGROUND CABLES
BEFORE DIGGING
FOR FREE CABLE LOCATING SERVICE
call collect
AREA CODE 213
621-3111
24 HOUR SERVICE
PACIFIC TELEPHONE

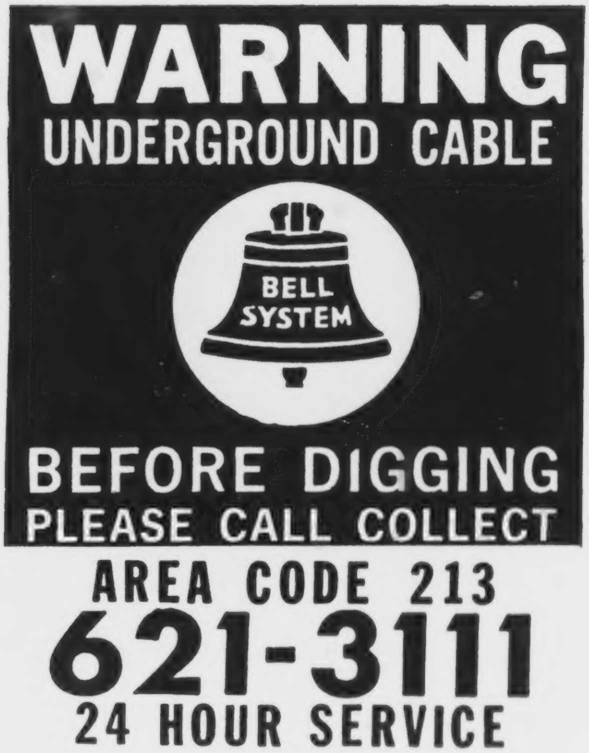

WARNING
UNDERGROUND CABLE
BELL SYSTEM
BEFORE DIGGING
PLEASE CALL COLLECT
AREA CODE 213
621-3111
24 HOUR SERVICE

Fig. 716. Typical identification and warnings signs used by a phone company to identify facilities

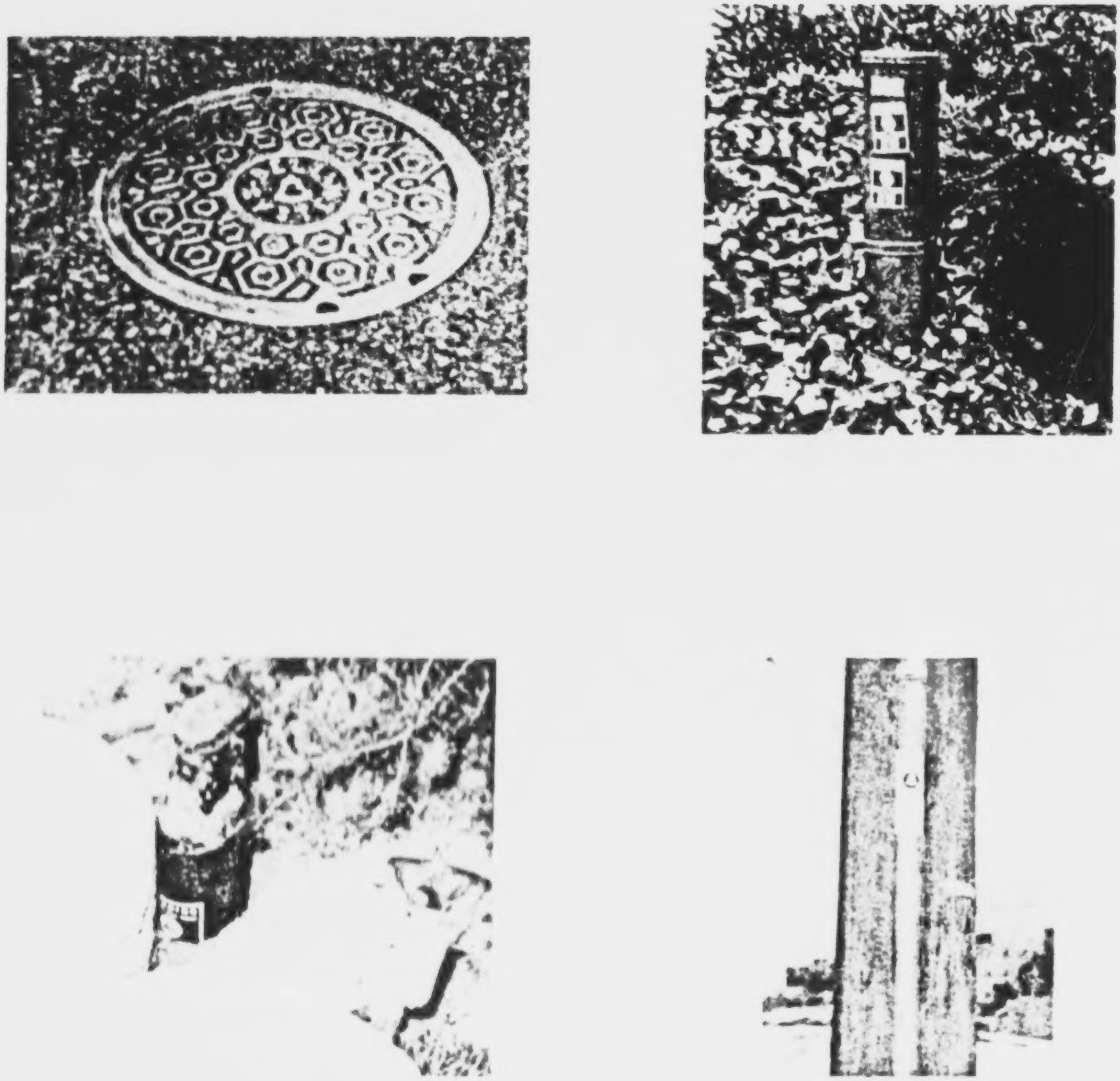


Fig 7.17 Typical identification that can be found near areas where the telephone company has installations.

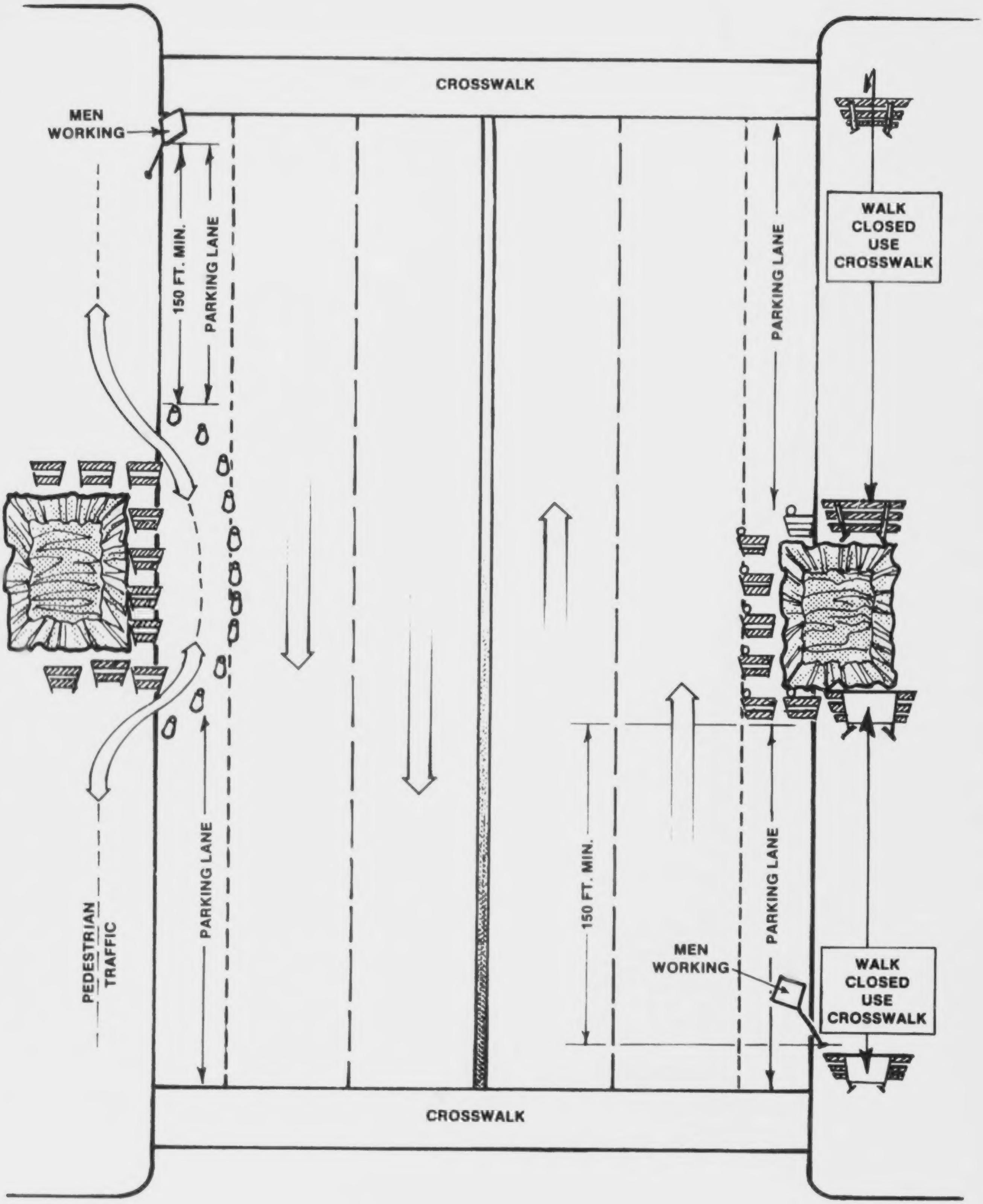

CROSSWALK
MEN WORKING
150 FT. MIN.
PARKING LANE
PARKING LANE
WALK CLOSED USE CROSSWALK
PARKING LANE
PEDESTRIAN TRAFFIC
150 FT. MIN.
MEN WORKING
PARKING LANE
WALK CLOSED USE CROSSWALK
CROSSWALK

Fig. 7.18 Pedestrian control

When work is to be done in a residential area, it is good public relations to advise the public what is to be done, how long it is expected to take, that all safety regulations will be observed, and that every effort will be taken not to disrupt the routine of the neighborhood.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

7.5E List the general safety rules for an excavation.

7.5F What type of shoring material should be used with trenches in running material?

7.5G List the underground utilities that could be damaged by water utility personnel searching for a leaking underground water main.

7.5H What would you tell the public when excavation work is planned in a residential neighborhood?

7.6 SAFETY AROUND WATER STORAGE FACILITIES

7.60 Slips and Falls

Industrial accident reports indicate that approximately 25 percent of all accidents are caused by slips and falls. The water utility industry is no different than other industries. Operators suffer from too many accidents due to slippery, wet surfaces. Slippery surfaces are common around storage facilities. They are caused by water or chemical spills on the floor. When cleaning a storage facility, one cannot avoid working on a wet surface.

When you must work inside a water tank, wear boots which have a special tread to help prevent a person from slipping. The area around a storage facility may be wet and could be the cause of slimes and growths which create slippery surfaces. Since rubber boots with special anti-slip tread are not always available, it may be necessary to treat the wet, slippery surface. There are many anti-slip coatings commercially available. Many of these anti-slip coatings may be applied with a brush, rollers or sprayed. These coatings usually have an abrasive (carbide crystals or ground walnut shells) substance suspended in a resin and use of them can change a slippery surface to a safe non-slip surface.

In addition to coatings, there are other products which you might consider. These are special treated strips of tape-like materials which can be affixed to areas where foot traffic is heavy. This type of tape material is often affixed every 6 to 12 inches (15 to 30 cm) along a slippery walkway.

7.61 Ladders

7.610 Fixed Ladders (Figure 7.19)

Most storage facilities are equipped with a fixed ladder which provides the only means of access to the top of an elevated facility (tank). A fixed ladder usually consists of individual rungs which are attached to the tank. A recommended type of fixed ladder should have provisions for use of a safety belt equipped with hooks and collar. The major hazard in the use of a fixed ladder is free fall. Other hazards include falls from carrying loads, running up or down, jumping from a ladder, and reaching too far out to the side while working from the ladders. The major hazard may be eliminated by the installation and proper use of available safety climbing devices.

7.611 Climbing Safety Devices (Figure 7.19)

Climbing safety devices are intended to prevent free fall of a climber if, for any reason, the climber should lose a grip or footing. There are two basic types of safety devices available.

1. A rail or cable attached to the ladder on which a sleeve or collar travels, and
2. A sleeve or collar which is fastened to the climber's safety belt by hooks and short lengths of chain.

The safety sleeve should be of a type which can be operated entirely by the person using the device to ascend or descend without having to continuously manipulate the safety sleeve. At normal climbing speed, the sleeve or collar slides up and down without hindrance. If the climber falls, a locking trigger or friction brake is activated and automatically stops the climber's fall.

Many hazards may be minimized by training personnel in how to go up and down a ladder.

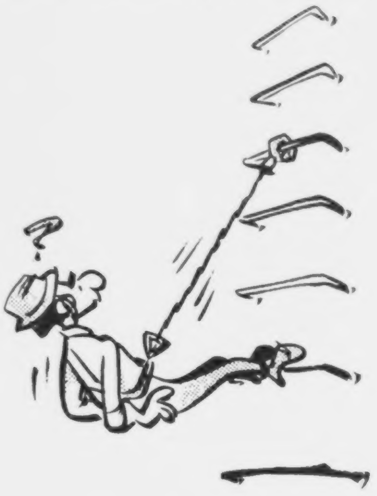
Potential ladder users should be:

1. Physically capable of exertion required, and
2. Without a previous history of heart ailment, dizzy or fainting spells, or other physical impairment which would make this climbing dangerous.

7.612 Training

Personnel should be properly trained in the use of ladders. The safe use of ladders requires two hands for the job. When climbing a ladder, use the following procedures:

1. Face the ladder and use both hands to grip the rungs or side rails firmly.
2. Place feet firmly on each rung before transferring full weight of body to each foot.
3. Climb deliberately, but without haste. Never run up or down and never slide down a ladder.
4. Never jump from a ladder. Check footing before stepping off a ladder.
5. Wear shoes with heels.
6. Always give your full attention when climbing. Be mindful that you are responsible for your own safety.



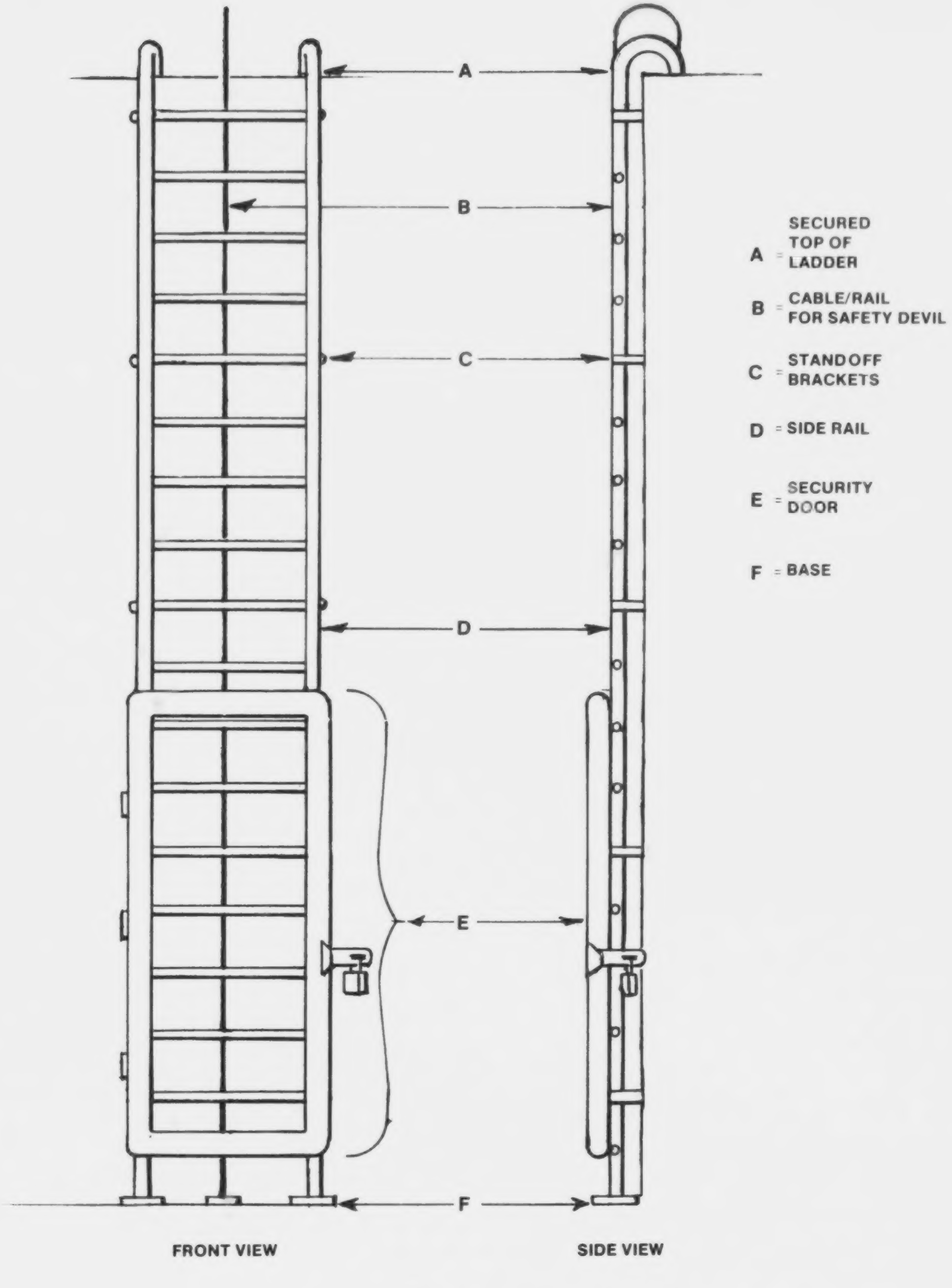

A
B
C
D
E
F
A = SECURED TOP OF LADDER
B = CABLE/RAIL FOR SAFETY DEVIL
C = STANDOFF BRACKETS
D = SIDE RAIL
E = SECURITY DOOR
F = BASE
FRONT VIEW
SIDE VIEW

Fig. 7.19 Fixed ladder with climbing safety device

7.613 Fixed Ladder Inspection

All fixed ladders and climbing devices should be inspected at least once a year. This inspection should be done by a person who is familiar with ladder inspection. Give prompt attention to correcting any defect which may be the potential cause of an accident. Some items to check for during a routine inspection include:

1. Loose, worn, and damaged rungs or side rails,
2. Corroded or damaged parts of the security door,
3. Corroded bolts or rivet heads where ladder is affixed to tank, and
4. Defects in climbing devices, including loose or damaged carrier rails or cables.

NEVER LEAVE A DEFECT UNCORRECTED. A ladder or safety device is only as safe as the person who is inspecting or using the ladder and climbing device.

7.62 Application of Coatings

The application of interior coatings to a storage facility (water tank) is necessary to preserve a tank interior in operating order. The application of a coating to a tank interior should not be taken lightly. Coordination and safety equipment are necessary to complete the job effectively. After the tank has been cleaned, it is recommended that it be sandblasted before applying any type of coating.

After the tank has been declared safe to enter (safe atmospheric conditions are discussed in Section 7.63, "Confined Spaces"), sandblasting may take place. The person operating the nozzle end of the sandblaster must wear protective clothing. This protection should include some type of clothing which has long sleeves — preferably a coverall type of clothing; a respirator and goggles or face shield should be used for face protection; and earplugs may be helpful because of noise.

Make certain that sufficient light is available and that sufficient air is available for the person doing the sandblasting. A respirator may not be sufficient. You may need to provide air by means of a portable air cylinder and an adequate length of air hose to a mask worn by the person doing the work.

After sandblasting has been completed, remove sand and paint debris from the tank. Make certain the tank has adequate air available for anyone working inside. After sand and debris are removed, scaffolding may be necessary for painters to apply the coating. Make certain that scaffolding meets your local safety requirements. If a mobile ladder stand is used instead of scaffolds, make certain that it meets safety requirements.

While painters are applying coating, make certain that they have air masks supplied with air and that someone is close by to check on their status periodically. Painters or any other person who must work in an enclosed area (tank) must have a safety harness with a safety line secure at the tank's entrance.

7.63 Confined Spaces

Covered water storage facilities are considered a confined space. This includes elevated tanks, facilities with roofs or covers, and underground facilities. Hazardous atmospheric conditions in confined spaces are a threat to the health of anyone who attempts to enter the facility. Other potential confined spaces encountered by operators include manholes, valve vaults, and any empty covered tank such as a dewatered filter or clear well.

When entering any confined space, the greatest consideration must be given to *DANGEROUS AIR CONTAMINATION* and *OXYGEN DEFICIENCY.* Many operators have lost their lives as a result of these two conditions. Use portable ventilation fans and *ALWAYS PROVIDE ADEQUATE VENTILATION.* Adequate ventilation will remove hazardous gases and replenish the oxygen. *BEFORE* entering a confined space test the atmosphere with gas detection instruments capable of detecting and measuring explosive gases, toxic conditions, and/or oxygen deficiency (see Section 7.20, "Monitoring Equipment"). These instruments should sound an alarm and/or produce a flashing light whenever hazardous atmospheric conditions are detected. Operators working in confined spaces should not be expected to read meters and determine whether or not a hazard exists. Operators who work around these conditions should be trained in applying artificial respiration.

Use the buddy system. Wear a safety harness and be certain your buddy is trained and knows what to do in the event that you get into trouble.

Safety is a must — never cut corners no matter how cumbersome the safety equipment may be — its use may save your life. Always review the *SAFETY NOTICE* before entering a confined space.

SAFETY NOTICE

Before anyone ever enters a tank for any reason, these safety procedures must be followed:

1. Test atmosphere in the tank for toxic and explosive gases and for adequate oxygen. Contact your local safety equipment supplier for the proper types of atmospheric testing devices. These devices should have alarms which are activated whenever an unsafe atmosphere is encountered;
2. Provide adequate ventilation, especially when painting. A self-contained positive-pressure breathing apparatus may be necessary when painting;
3. All persons entering a tank must wear a safety harness; and
4. One person must be at the tank entrance and observing the actions of all people in the tank. An additional person must be readily available to help the person at the tank entrance with any rescue operation.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

7.6A How do anti-slip coatings prevent slippery surfaces?

7.6B What are the two basic types of safety devices used by operators when climbing fixed ladders?

7.6C What are the physical requirements for operators who must climb fixed ladders?

7.6D A safety inspection of a fixed ladder should include what items?

7.6E Why do storage tanks need interior coatings?

7.6F What atmospheric hazards may be encountered in a confined space?

7.7 WORKING NEAR NOISE

Operators must be protected against the effects of exposure to noise when the sound levels exceed the limits listed in Table 7.4. Engineering methods of controlling noise must be initiated whenever possible. If noise levels cannot be controlled within acceptable limits, operators must be provided and use approved ear plugs, muffs, and/or personal protective equipment.

TABLE 7.4 HEARING PROTECTION[a]

1. When employees are exposed to loud or extended noise, ear plugs and/or protective devices shall be provided and employees shall wear them accordingly.
2. Protection against the effects of noise exposure shall be provided when sound levels exceed those shown in rule number six. These measurements shall be made on the A-scale of a standard sound level meter at slow response.
3. When employees are subjected to sound levels exceeding those listed in rule number six, feasible administrative and/or engineering controls shall be utilized. If such controls fail to reduce employee exposure to within the permissible noise levels listed in this table, personal protective equipment shall be provided and used.
4. Plain cotton shall not be considered acceptable as an ear plug.
5. Machinery creating excessive noise shall be equipped with mufflers.
6. Employees shall not be exposed to noise which exceeds the levels listed below for a time period not to exceed those listed below.

Duration: Hours Per Day	Sound Level:dBA Slow Response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
one fourth (¼) hour, or less	115

---

[a] Occupational Safety and Health Standards, Subpart G, Paragraph 1910.94, Noise Exposure

7.8 SAFETY INSPECTIONS

Regular safety inspections are a good way to be sure that equipment and facilities receive a regular safety review. To insure that important items are not overlooked or forgotten, inspection forms or reports are very helpful. These forms also provide a record of who inspected what items and when. Figures 7.20 and 7.21 are typical "Safety Inspection Reports."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

7.7A How can operators protect themselves from excessive noise.

7.8A Why are safety inspection forms helpful?

7.9 ARITHMETIC ASSIGNMENT

There is no arithmetic assignment for this chapter.

7.10 ADDITIONAL READING

1. *NEW YORK MANUAL*, Chapter 19, "Treatment Plant Maintenance and Accident Prevention."
2. *TEXAS MANUAL*, Chapter 21, "Safety."
3. Chapter 20, "Safety," in *WATER TREATMENT PLANT OPERATION*, Volume II. Available from Ken Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819. Price $30.00.
4. *SAFETY PRACTICE FOR WATER UTILITIES. M3*. Obtain from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235. Order No. 30003. Price to members, $16.00; nonmembers, $20.00.
5. *SAFETY TALKS.* A series of 52 lectures on common water utility safety practices. Order No. 70010. One to five subscriptions, price to members, $11.50 each; non-members, $14.00 each. Available from Computer Services, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235.
6. *STANDARD FIRST AID AND PERSONAL SAFETY*. Available from your local Area Chapter of The American Red Cross. Price $5.00.

End of Lesson 2 of 2 Lessons on SAFETY

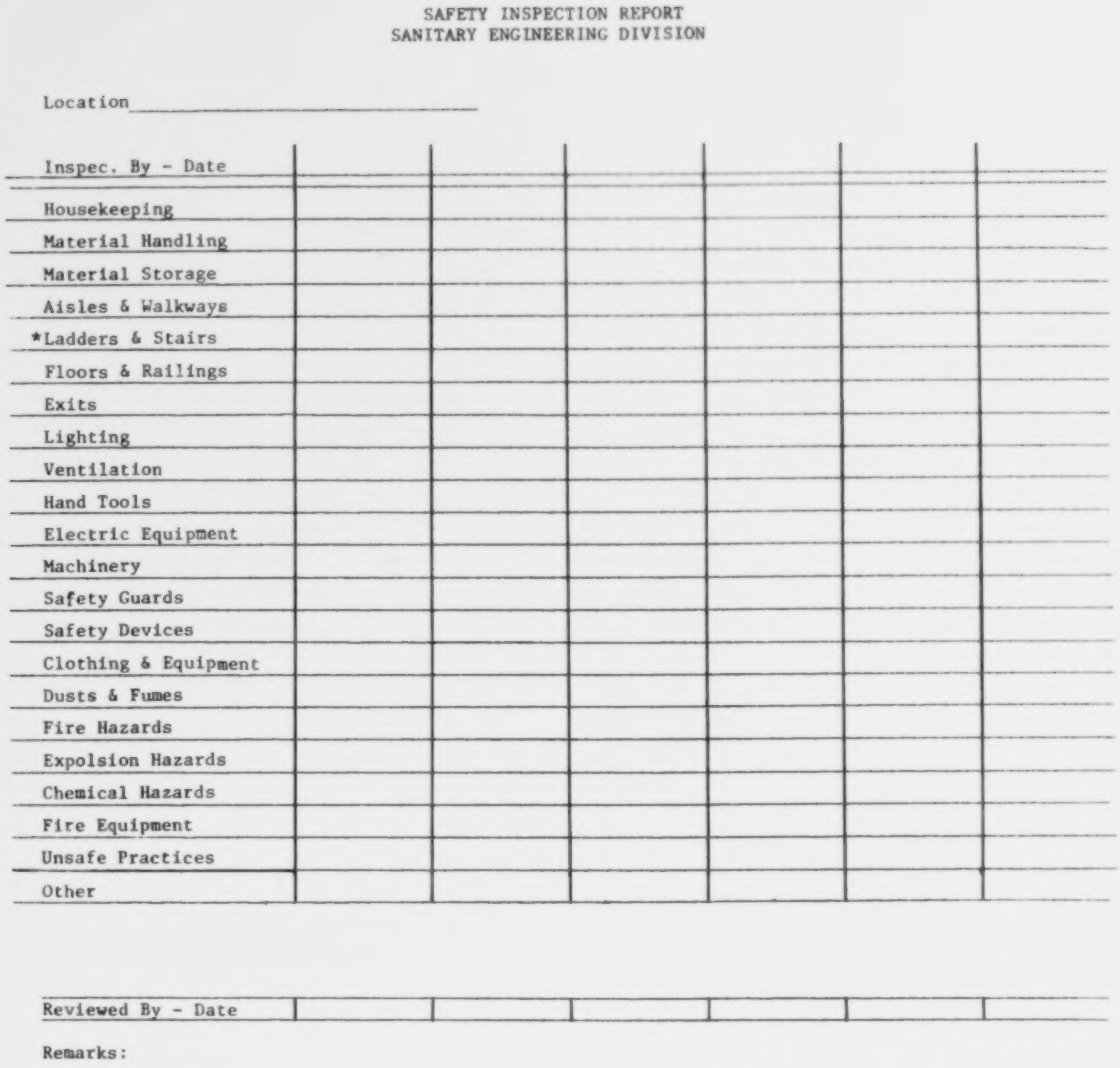
DISCUSSION AND REVIEW QUESTIONS

Chapter 7. SAFETY

(Lesson 2 of 2 Lessons)

Write the answers to these questions in a notebook before continuing with the Objective Test on page 390. The problem numbering continues from Lesson 1.

12. Where do rotating, reciprocating and transverse (crosswise) motions on pumps create hazards?
13. Why must water utility operators work in streets?
14. Where are flagmen required?
15. How can cave-ins be prevented?
16. How can the public be protected from excavation hazards?
17. How can you reduce the chances of operators slipping and falling on slippery surfaces?



SAFETY INSPECTION REPORT
SANITARY ENGINEERING DIVISION

Location ______________________

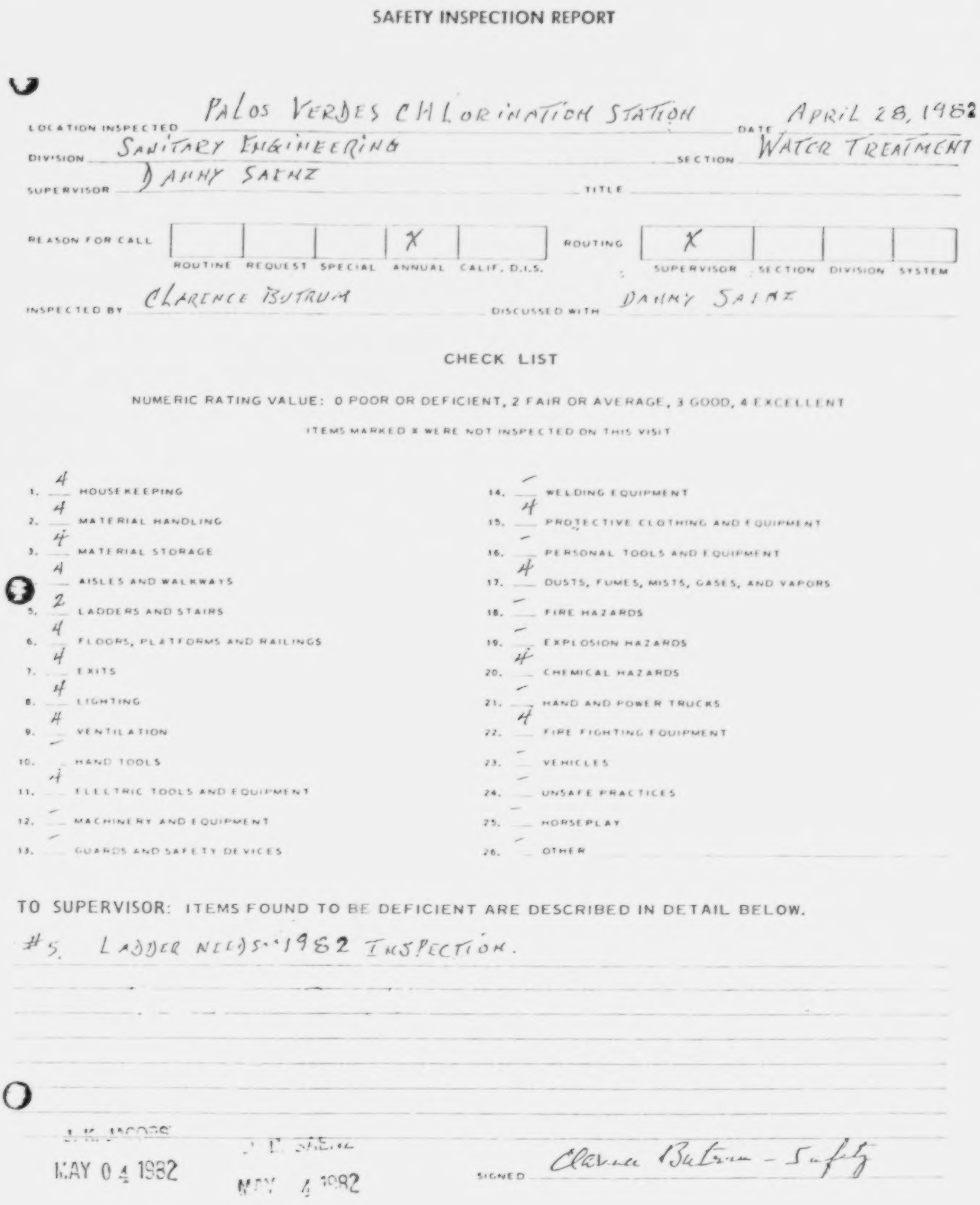
Inspec. By - Date						
Housekeeping						
Material Handling						
Material Storage						
Aisles & Walkways						
*Ladders & Stairs						
Floors & Railings						
Exits						
Lighting						
Ventilation						
Hand Tools						
Electric Equipment						
Machinery						
Safety Guards						
Safety Devices						
Clothing & Equipment						
Dusts & Fumes						
Fire Hazards						
Expolsion Hazards						
Chemical Hazards						
Fire Equipment						
Unsafe Practices						
Other						

Reviewed By - Date						

Remarks:

*Note ladders

Fig. 7.20 Safety inspection report used by operators to inspect facilities



SAFETY INSPECTION REPORT

LOCATION INSPECTED PALOS VERDES CHLORINATION STATION DATE APRIL 28, 1982
DIVISION SANITARY ENGINEERING SECTION WATER TREATMENT
SUPERVISOR DANNY SAENZ TITLE

REASON FOR CALL	☐ ROUTINE	☐ REQUEST	☐ SPECIAL	☒ ANNUAL	☐ CALIF. D.I.S.	ROUTING	☒ SUPERVISOR	☐ SECTION	☐ DIVISION	☐ SYSTEM

INSPECTED BY CLARENCE BUTRUM DISCUSSED WITH DANNY SAENZ

CHECK LIST

NUMERIC RATING VALUE: 0 POOR OR DEFICIENT, 2 FAIR OR AVERAGE, 3 GOOD, 4 EXCELLENT

ITEMS MARKED X WERE NOT INSPECTED ON THIS VISIT

1. 4 HOUSEKEEPING
2. 4 MATERIAL HANDLING
3. 4 MATERIAL STORAGE
4 AISLES AND WALKWAYS
5. 2 LADDERS AND STAIRS
6. 4 FLOORS, PLATFORMS AND RAILINGS
7. 4 EXITS
8. 4 LIGHTING
9. 4 VENTILATION
10. – HAND TOOLS
11. 4 ELECTRIC TOOLS AND EQUIPMENT
12. – MACHINERY AND EQUIPMENT
13. – GUARDS AND SAFETY DEVICES
14. – WELDING EQUIPMENT
15. 4 PROTECTIVE CLOTHING AND EQUIPMENT
16. – PERSONAL TOOLS AND EQUIPMENT
17. 4 DUSTS, FUMES, MISTS, GASES, AND VAPORS
18. – FIRE HAZARDS
19. – EXPLOSION HAZARDS
20. 4 CHEMICAL HAZARDS
21. – HAND AND POWER TRUCKS
22. 4 FIRE FIGHTING EQUIPMENT
23. – VEHICLES
24. – UNSAFE PRACTICES
25. – HORSEPLAY
26. – OTHER

TO SUPERVISOR: ITEMS FOUND TO BE DEFICIENT ARE DESCRIBED IN DETAIL BELOW.

#5. LADDER NEEDS 1982 INSPECTION.

J. K. JACOBS
MAY 0 4 1982

J. E. SAENZ
MAY 4 1982

SIGNED Clarence Butrum - Safety

Fig. 7.21 Safety inspection report used by safety section personnel

SUGGESTED ANSWERS

Chapter 7. SAFETY

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 346.

7.0A Two very important aspects of a safety program are:

1. Making people aware of unsafe acts, and
2. Conducting and/or participating in regular safety training programs.

7.0B Management's responsibilities for safety include:

1. Establishing a safety policy,
2. Assigning responsibility for accident prevention,
3. Appointing a safety officer,
4. Establishing realistic goals and periodically revising them, and
5. Evaluating the results of the program.

7.0C Operators' responsibilities for safety include:

1. Performing their jobs in accordance with established safe procedures,
2. Recognizing the responsibility for their own safety and that of fellow operators,
3. Reporting all injuries,
4. Reporting all observed hazards,
5. Actively participating in the safety programs.

Answers to questions on page 347.

7.1A An accident is that occurrence in a sequence of events that usually produces unintended injury, death or property damage.

7.1B The brakes on a vehicle are working properly when they are able to stop the vehicle without grabbing or pulling to one side.

7.1C The principal reasons for unsafe acts include ignorance, indifference, poor work habits, laziness, haste, poor physical condition, and temper.

7.1D Laziness affects the speed and quality of work. Laziness also affects safety because safety requires an effort. In most jobs you cannot reduce your "safety effort" and still maintain the same level of safety, even if you slow down or lower your quality standards.

Answers to questions on page 350.

7.1E Before towing a trailer, inspect:

1. Rear, turn signal, and brake lights.
2. Tire tread and inflation,
3. Wheel attachment,
4. Trailer brake operation if equipped with brakes,
5. Safety chain.

7.1F All cigarettes and flames should be put out before attaching cables to charge a battery because a spark can ignite the hydrogen gas from the battery fluid.

7.1G Good safety practices for using boats include:

1. An annual safety inspection,
2. A safety vest or flotation device for each occupant,
3. Not overloading a boat, and
4. At least two people should go out in a boat.

7.1H A corrosive chemical is any chemical which may weaken, burn and/or destroy a person's skin or eyes.

7.1I A tailgate safety session is usually held near the work site and new and old safety hazards and safer approaches and techniques to deal with the problems of the day or week are discussed.

Answers to questions on page 353.

7.2A Some of the typical locations in a water utility where it is necessary to monitor the atmosphere before entering include underground regulator vaults, solution vaults, manholes, tanks, trenches and other confined spaces.

7.2B The standby person outside the confined area should check continuously on the status of personnel working in the confined space. Should a person working in the confined space be rendered unconscious due to asphyxiation or lack of oxygen, the standby at the surface could enter into the space by:

1. Securing a backup rescue person, and
2. Putting on the correct type of respiratory protective equipment.

7.2C A mixture of air and gas is considered hazardous when the mixture exceeds 20 percent of the Lower Explosive Limit (LEL).

Answers to questions on page 355.

7.2D Items of protective clothing for operators include:

1. Safety toe (hard toe) shoes,
2. Safety prescription glasses,
3. Safety (hard) hats,
4. Ear plugs,
5. Safety glasses (non-prescription),
6. Safety goggles,
7. Face shields,
8. Respirators and mask,
9. Canvas gloves,
10. Rubber gloves for use with corrosive chemicals,
11. Safety aprons,
12. Leggings/knee pads/safety belts or harnesses,
13. Safety toe caps, and
14. Protective clothing (lab coats or rubber suits).

7.2E Liquids spilled on floors can be cleaned up by using nonflammable absorbent materials.

7.2F The steps to safe lifting include:

1. Keep feet parted — one along the side of and one behind the object,
2. Keep back straight — nearly vertical,
3. Tuck in your chin,
4. Grip the object with the whole hand,
5. Tuck elbows and arms in,
6. Keep body weight directly over feet, and
7. Lift slowly.

7.2G Before attempting to work on electrical motors, be sure to lock out and tag all of the electrical switches.

Answers to questions on page 358.

7.3A The well operator has the responsibility to preserve the quality of the well through preventive maintenance of the area where the well is located. This responsibility also extends to good housekeeping to prevent the development of safety hazards to operators working around the well site.

7.3B A sanitary seal on a well is used to keep contaminated water and debris from entering around the well casing and reaching the groundwater.

7.3C Surface openings on top of a well that must be protected against the entrance of surface water or debris into the well include:

1. Well casing vents,
2. Gravel tubes,
3. Sounding tube,
4. Conduits, and
5. Pump motor base seal.

Answers to questions on page 359.

7.3D Hydrochloric acid must be handled carefully because it is extremely corrosive. Hydrochloric acid can burn your eyes and skin, if inhaled it will cause coughing and choking, and if swallowed will cause corrosion of your insides (including your circulatory system).

7.3E Sulfamic acid has advantages over hydrochloric acid for acid cleaning a well. Granular sulfamic acid is non-irritating to dry skin and its solution gives off no fumes except when reacting with incrusting materials. Spillage, therefore, presents no hazard and handling is easier, cheaper, and safer.

7.3F Although the granular form of sulfamic acid is non-irritating to the skin and it gives off no fumes, rubber gloves should still be used because hands may become wet from perspiration and the acid will cause burns on the skin. Safety goggles or glasses, preferably a face shield, should be used in case granules are blown into the face and/or eyes. Acid should always be added slowly to the water.

Answers to questions on page 361.

7.3G When handling hypochlorite use rubber gloves, a rubber apron, and a face shield.

7.3H Glassy phosphate should be handled very carefully because the glass particles are very sharp and can cut your skin. Use heavy duty gloves when handling. Respiration or a face shield should be worn.

7.3I If no one working for a water utility is knowledgeable about electrical circuits, the utility should contact an electrician from a local electrical firm.

7.3J Items that should be included in a safety inspection of a well site include:

1. Cleanliness of site,
2. Locks on electrical panels,
3. Fencing around site, and
4. Caution/warning signs in place.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 362.

7.4A Pumps are used to move liquids, air or gas. They are also used to increase pressures and energy of fluids.

7.4B Moving parts on a pump which require guards include rotation members, reciprocating arms, moving parts, and meshing gears. This includes rotating shafts, couplings, belts, pulleys, chains, and sprockets.

7.4C Rotating devices can injure you by gripping your clothing or hair and possibly forcing an arm or hand into a dangerous position.

7.4D The basic requirement for an enclosed guard is that it must prevent hands, arms or any other part of an operator's body from making contact with dangerous moving parts. A good guarding system eliminates the possibility of the operator or another worker placing their hands near hazardous moving parts.

Answers to questions on page 367.

7.4E *ALWAYS* isolate the power *BEFORE* beginning any maintenance on a pump.

7.4F Safety planning includes identifying potential safety hazards *BEFORE* starting a job and deciding how they can be avoided. Safety coordination requires that supervisory personnel be notified and necessary approvals obtained *BEFORE* starting any maintenance work.

7.4G Never work on any equipment when it is hanging from a sling in mid-air because the equipment could slip from the sling and fall on you.

7.4H Lubricants and fuels should be stored in a separate facility from other storage areas because of the potential fire hazard.

Answers to questions on page 375.

7.5A When channeling traffic flow through a work area, consider the following items:

1. Prewarn,
2. Sign properly,
3. Regulate speed, and
4. Guide properly.

7.5B Persons who must work in streets should wear their normal clothing plus a high visibility shirt, poncho, vest or coat. This clothing should be colored red or safety orange. A safety hat (hard hat) should be worn whenever you are near traffic.

7.5C Hand signaling motions commonly used by flagmen include (1) slow, (2) stop, and (3) proceed.

7.5D The following rules should be considered when setting up street warning devices:

1. Whenever possible, use a flagman when setting up or breaking down the work area;
2. Use more, rather than too little, warning equipment at the work area;
3. Anticipate the unexpected and irrational acts of pedestrians and vehicles;
4. Do not use the same set up on streets with fast moving traffic as would be used on slow traffic streets; and
5. Keep all tools and materials within the confines of the protected area.

Answers to questions on page 382.

7.5E General safety rules for an excavation include:

1. Employer must inspect excavations for hazards before employees may work in or adjacent to the excavation.

2. Excavations must be inspected by qualified persons after each rain storm, earthquake or other hazard.
3. Large excavations must be inspected daily.
4. Proper, qualified supervisors shall be on site at all times during excavations.
5. Safety provisions must be taken to protect workers installing or removing shoring systems.
6. Spoil must be kept back at least two feet from the edge of all excavations.
7. Safe and convenient access to an excavation must be provided.
8. Effective barriers must be installed at excavations adjacent to mobile equipment.
9. Water must not be allowed to accumulate in any excavation.

7.5F Trenches in running material should have sheet piling or equivalent solid sheeting, longitudinal stringers and cross braces.

7.5G Underground utilities that could be damaged by water utility personnel searching for a leaking underground water main include telephone cables, television cables, electrical services, gas mains and occasionally storm water and sewer lines.

7.5H When work is to be done in a residential neighborhood, it is good public relations to advise the public what is to be done, how long it is expected to take, that all safety regulations will be observed, and that every effort will be taken not to disrupt the routine of the neighborhood.

Answers to questions on page 384.

7.6A Anti-slip coatings usually have an abrasive (carbide crystals or ground walnut shells) substance suspended in a resin which can change a slippery surface to a safe non-slip surface.

7.6B The two basic types of safety devices used by operators when climbing fixed ladders are:

1. A rail or cable, which is fixed to the ladder, on which a sleeve or collar travels, and
2. A sleeve or collar which is fastened to the climber's safety belt by hooks and short lengths of chain.

7.6C Physical requirements for operators who must climb fixed ladders include:

1. Physically capable of the exertion required, and
2. Without a previous history of heart ailment, dizzy or fainting spells, or other physical impairment which would make this climbing dangerous.

7.6D A safety inspection of a fixed ladder should include checking for:

1. Loose, worn, and damaged rungs or side rails,
2. Corroded or damaged parts of the security door,
3. Corroded bolts or rivet heads where ladder is affixed to tank, and
4. Defects in climbing devices, including loose or damaged carrier rails or cables.

7.6E Storage tanks need interior coatings to preserve a tank interior in operating order.

7.6F Atmospheric hazards that may be encountered in a confined space include explosive conditions, toxic gases and/or oxygen deficiency.

Answers to questions on page 385.

7.7A Operators can protect themselves from excessive noise by using approved ear plugs, muffs, and/or personal protective equipment.

7.8A Safety inspection forms are helpful because (1) they provide a record of who inspected what items and when, and (2) they help prevent the overlooking of important safety items.

OBJECTIVE TEST

Chapter 7. SAFETY

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to the multiple-choice questions.

True — False

1. Safety is a form of preventive maintenance which includes equipment and machinery and its proper handling.
   1. True
   2. False
2. People miss more time from work from on-the-job accidents than from off-the-job accidents.
   1. True
   2. False
3. Offensive drivers are safe drivers.
   1. True
   2. False
4. Very few accidents related to trailer towing occur while simply coupling the trailer to the vehicle.
   1. True
   2. False
5. Boats can be safely loaded in excess of their rated capacity.
   1. True
   2. False
6. Corrosive chemicals only have low pH values.
   1. True
   2. False

7. YOU are the key individual to an effective safety program.
   1. True
   2. False
8. Sawdust should be used as an absorbent for cleaning up spilled chemicals.
   1. True
   2. False
9. You can safely stand in water when working on electrical equipment.
   1. True
   2. False
10. New well pumps should be disinfected.
    1. True
    2. False
11. Electrical equipment and wiring must be protected from environmental deterioration.
    1. True
    2. False
12. While accidents due to contact with rotating objects are not frequent, the severity of injury is very high.
    1. True
    2. False
13. Enclosed guards permit access to dangerous moving parts at all times.
    1. True
    2. False
14. In order to build up head, a pump should be operated against a closed discharge valve.
    1. True
    2. False
15. Fire extinguishers should be stored inside a fuel storage area.
    1. True
    2. False
16. The person installing traffic control devices should drive through the area to verify the effectiveness of the work area protection system.
    1. True
    2. False
17. Proper shoring can contribute to cave-ins.
    1. True
    2. False
18. When installing shoring braces or screw jacks, start at the bottom of the trench and work up to the top.
    1. True
    2. False
19. The major hazard in the use of a fixed ladder is free fall.
    1. True
    2. False
20. Slippery surfaces may be caused by water or chemical spills on the floor.
    1. True
    2. False

Multiple Choice

21. Items in a good safety program include
    1. Appointing a safety officer.
    2. Assigning responsibility for accident prevention.
    3. Establishing a safety policy.
    4. Reporting all injuries.
    5. Reporting all observed hazards.
22. A good driver
    1. Is courteous to other drivers.
    2. Knows and observes all traffic regulations.
    3. Makes sure that all the lights are operating properly.
    4. Sometimes signals in advance of any directional changes.
    5. Uses the seat belt.
23. Unsafe acts may be caused by
    1. Ignorance.
    2. Indifference.
    3. Laziness.
    4. Poor work habits.
    5. Temper.
24. Before starting to drive a vehicle towing a trailer
    1. Check trailer hitch and tongue.
    2. Inspect rear, turn signal, and brake lights.
    3. Inspect trailer brake operation.
    4. Observe safety chain.
    5. Observe tire tread and inflation.
25. Common uses of boats by water utility operators include
    1. Disinfecting product water.
    2. Inspecting reservoirs.
    3. Pumping sludge.
    4. Sampling.
    5. Surveying reservoirs.
26. Who is primarily responsible for your safety?
    1. Management
    2. You
    3. Your co-workers
    4. Your safety officer
    5. Your supervisor
27. On floors where water or chemicals are commonly spilled, cover the floors with
    1. Catwalks.
    2. Linoleum.
    3. Safety tread.
    4. Tile.
    5. Wood.
28. Slippery floors may be prevented by
    1. Collecting drips in appropriate gutters.
    2. Collecting drips in drip pans.
    3. Keeping floors covered with algae.
    4. Keeping floors slip resistant.
    5. Using splash guards to deflect drips.

29. Typical injuries resulting from handling and lifting include
    1. Back injuries.
    2. Eye strain.
    3. Hearing loss.
    4. Hernias.
    5. Strains and sprains.

30. Unsafe work practices which cause handling and lifting injuries include
    1. Carrying too heavy a load.
    2. Correct gripping.
    3. Failing to observe proper hand clearance.
    4. Failing to use proper equipment.
    5. Proper lifting.

31. Sources of pollution which may contaminate groundwater include
    1. Artesian aquifers.
    2. Mining operations.
    3. Septic tanks.
    4. Solid waste disposal sites.
    5. Subsurface leaching systems.

32. A new well could be contaminated from
    1. Contaminated packing gravel.
    2. Disinfection solution.
    3. Drilling tools and mud.
    4. Surface runoff.
    5. Topsoil falling into well.

33. Wells which are no longer useful should be abandoned and plugged to
    1. Assure that groundwater is protected for further use.
    2. Eliminate the potential physical hazard to people.
    3. Prevent other people from using well.
    4. Protect nearby wells from contamination.
    5. Reduce maintenance costs.

34. Moving parts on a pump which require guards include
    1. Belts and pulleys.
    2. Chains and sprockets.
    3. Couplings.
    4. Impellers.
    5. Shafts.

35. A traffic delineation device is another name for a
    1. Detour.
    2. Flagman.
    3. Speed regulating sign.
    4. Traffic cone.
    5. Traffic sign.

36. Traffic control systems are used on street work sites to protect the
    1. Equipment.
    2. Facility.
    3. Motorist.
    4. Pedestrian.
    5. Work force.

37. Excavations must be inspected by qualified persons after each
    1. Earthquake.
    2. Hot day.
    3. Rainy day.
    4. Shift leaves the job.
    5. Time a truck goes by.

38. Exits must be provided within ______ feet of every worker for all occupied trenches four or more feet deep.
    1. 25
    2. 50
    3. 75
    4. 100
    5. 150

39. The chances of slipping and falling on slippery surfaces can be reduced by
    1. Affixing specially treated strips of tape-like materials.
    2. Applying anti-slip coats to the surfaces.
    3. Mopping up the wet surface when it become slippery.
    4. Preventing the growth of slime.
    5. Wearing boots with a special anti-slip tread.

40. Hazards encountered by operators using a fixed ladder include
    1. Falls from carrying loads.
    2. Falls from ladder caused by electricity.
    3. Jumping from ladder.
    4. Reaching too far out.
    5. Running up or down.

End of Objective Test

APPENDIX

Final Examination

How to Solve Water Distribution System Arithmetic Problems

Water Abbreviations

Water Words

Subject Index

WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

FINAL EXAMINATION

AND

SUGGESTED ANSWERS

This final examination was prepared TO HELP YOU review the material in this manual. The questions are divided into four types:

1. True-False,
2. Multiple Choice,
3. Short Answers, and
4. Problems.

To work this examination:

1. Write the answers to each question in your notebook.
2. After you have worked a group of questions (you decide how many), check your answers with the suggested answers at the end of this exam, and
3. If you missed a question and don't understand why, reread the material in this manual.

You may wish to use this examination for review purposes when preparing for civil service and certification examinations.

Since you have already completed this course, you do not have to send your answers to California State University, Sacramento.

True — False

1. Water distribution system operators are responsible for the drinking water of their community.

   1. True
   2. False

2. A surge tank is used to store filtered water from a treatment plant.

   1. True
   2. False

3. Operators should know how high the water level in a water storage tank should be at the start of each day.

   1. True
   2. False

4. Excessive water distribution system pressures may damage the consumer's plumbing fixtures.

   1. True
   2. False

5. The use of wells increases the requirements for operational storage in a distribution system.

   1. True
   2. False

6. All excavation work must at all times be under the immediate supervision of someone with the authority to modify the shoring system as necessary to provide adequate safety.

   1. True
   2. False

7. Contaminants can enter the water supplied to the distribution system through the source of the water supply.

   1. True
   2. False

8. Improper chlorination in water treatment plants can cause tastes and odors in water delivered to consumers.

   1. True
   2. False

9. Distribution systems should always be under a continuous positive pressure at all times.

   1. True
   2. False

10. Distribution system reservoirs should be full at the end of the peak demand period.

    1. True
    2. False

11. Cold water requires shorter chlorine disinfection time than warm water.

    1. True
    2. False

12. Chlorine gas used for disinfection tends to increase the pH of water.

    1. True
    2. False

13. Chlorine reacts with inorganic matter to form chlororganic compounds, including trihalomethanes.

    1. True
    2. False

14. A cigarette can ignite hydrogen gas from the fluid of a battery.

    1. True
    2. False

25. Before attempting to work on electrical motors, be sure to lock out and tag all of the electrical switches.

    1. True
    2. False

Multiple Choice

1. Responsibilities of water distribution system operators include
   1. Being sure that adequate amounts of water and pressure are available during times of emergency.
   2. Building water distribution system facilities to collect, store, transport and treat water.
   3. Designing water distribution system facilities to distribute water to people and industries.
   4. Insuring that safe and pleasant drinking water is delivered to everyone's tap.
   5. Making water distribution system facilities do their intended job.
2. Abnormal conditions encountered by operators of water storage facilities include
   1. Broken mains.
   2. Excessive system pressures.
   3. Fire demands.
   4. Out-of-service pumps.
   5. Stale water.
3. Problems caused by freezing conditions in elevated tanks include
   1. Damage to walls.
   2. Depth sensors (floats) damaged.
   3. Interior coating failure.
   4. Interior ladders distorted.
   5. Storage of water to meet future demands.
4. Water hammer can be caused by
   1. Movement of fittings.
   2. Pumps suddenly starting.
   3. Pumps suddenly stopping.
   4. Valves quickly closing.
   5. Valves quickly opening.
5. Steel pipe may be lined with
   1. Asbestos cement.
   2. Bituminous material.
   3. Cathodic protection.
   4. Cement mortar.
   5. Epoxy.
6. Shoring requirements depend on
   1. Depth of trench.
   2. Laws and regulations.
   3. Nearby activities.
   4. Soil conditions.
   5. Width of trench.
7. Physical qualities of water important to consumers include
   1. Color.
   2. Hardness.
   3. Odor.
   4. Taste.
   5. Temperature.
8. Elements of a water distribution system surveillance program include
   1. Analysis of peak demand flow records.
   2. Appearance of stored water.
   3. Evidence of unauthorized entrance to facilities.
   4. Storm damage.
   5. Vandalism.
9. Samples are routinely collected from water distribution systems and tested for
   1. Chlorine residuals.
   2. Coliform bacteria.
   3. Hardness.
   4. Tastes and odors.
   5. Turbidity.
10. Inaccurate meter registration results from
    1. Corrosion.
    2. Deposition.
    3. Maintenance.
    4. Testing.
    5. Wear.
11. Inorganic reducing chemicals found in source waters that react rapidly with chlorine include
    1. Ammonia.
    2. Calcium chloride.
    3. Hydrochloric acid.
    4. Hydrogen sulfide.
    5. Sodium chloride.
12. Which of the following precautions would you take when shutting down a hypochlorinator for a short duration?
    1. Lock out circuits
    2. Obtain another hypochlorinator
    3. Turn off gas
    4. Turn off hypochlorinator
    5. Turn off water supply pump
13. Important aspects of a safety program include
    1. Conducting regular safety programs.
    2. Keeping public informed of utility's safety record.
    3. Maintaining industrial accident statistics.
    4. Making operators aware of unsafe acts.
    5. Preventing maintenance records from getting lost.
14. Good safety practices for operators using boats include
    1. Annual safety inspection.
    2. Flotation device for each occupant.
    3. Only one person in the boat.
    4. Overloading the boat.
    5. Using the boat on stormy days.
15. Fires involving zinc or sodium should be extinguished by the use of
    1. Fine dry soda ash.
    2. Foam.
    3. Graphite.
    4. Sand.
    5. Water.

Short Answers

1. What does a water distribution system operator do?
2. What are the major sources of contaminants in a water distribution system?
3. How can water treatment plants contribute to water quality problems in a water distribution system?
4. Why should operators become certified?
5. What are the advantages of distribution system water storage?
6. List the disadvantages of using concrete pipe for water distribution system mains.

7. List the buried utilities that must be located before excavating.
8. Why should field crews be on the lookout for any unauthorized construction activity?
9. How can water utilities avoid serious valve problems?
10. Why should utilities have a work order system?
11. How can water mains be kept clean during construction and repair?
12. List the typical locations where a water utility operator should monitor atmospheric conditions before entry.
13. What is the job of the standby person outside a confined space work area?
14. List the items that should be inspected during the safety inspection of a fixed ladder.
15. What is breakpoint chlorination?

Problems

1. Convert a flow of 300 GPM to MGD.
2. Convert a flow of 60 GPD to milliliters per minute.
3. Convert a flow of 100 m*L*/min to GPD.
4. Determine a chlorinator setting in pounds per 24 hours to treat a flow of 0.90 MGD with a chlorine dose of 2.5 mg/*L*.
5. Calculate the volume of water in gallons in a rectangular water storage tank 30-feet long, 12-feet wide and the water is 6-feet deep.
6. Calculate the volume of water in gallons in a circular storage tank 25 feet in diameter when the water is 8-feet deep.
7. Water is 23-feet deep in a water storage tank. What is the water pressure on the bottom of the tank in psi?
8. The discharge pressure gage on a pump reads 43 psi. What is the discharge pressure head in feet?
9. Convert a flow rate of three cubic feet per second to gallons per minute.
10. Convert a flow rate of 300 gallons per minute to cubic feet per second.
11. Calculate the flow in cubic feet per second in a 15-inch diameter pipe when the velocity is 2.4 feet per second.
12. A six-inch water line is to be flushed at a velocity of five feet per second. What should be the reading on the flow meter in gallons per minute?
13. Estimate the flow in gallons per minute from a pump if a 750 gallon tank fills in three minutes.
14. A water meter is tested in a laboratory. The meter reads 195 gallons. The actual flow was measured in a volumetric tank as 197 gallons. Determine the meter accuracy as a percentage.
15. A trench four-feet wide, 390-feet long and 6.3 feet deep is to be excavated for a water main. How many cubic yards of soil must be excavated for the water main?
16. A flow meter indicates a flow of 90 GPM. How [illegible] will it take to fill a 16,200 gallon storage tank?
17. What should be the chlorine dose of a water that has a chlorine demand of 1.3 mg/*L* if a residual of 0.4 mg/*L* is desired?
18. What should be the setting on a chlorinator in pounds per 24 hours if a pump usually delivers approximately 520 gallons per minute and the desired chlorine dose is 2.5 mg/*L*?
19. Estimate the desired strength (as a percent chlorine) of a hypochlorite solution being pumped by a hypochlorinator that delivers 100 gallons per day. The water being treated requires a chlorine feed rate of 19 pounds of chlorine per day.
20. A water treatment plant has seventeen 150-pound chlorine cylinders in storage. The plant uses an average of 127 pounds of chlorine per day. How many days' supply of chlorine is in storage.

SUGGESTED ANSWERS FOR FINAL EXAMINATION

True — False

1. True Water distribution system operators are responsible for the drinking water of their community.
2. False A clear well is used to store filtered water from a treatment plant.
3. True Operators should know how high the water level in a water storage tank should be at the start of each day.
4. True Excessive water distribution system pressures may damage the consumer's plumbing fixtures.
5. False The use of wells decreases the requirements for operational storage in a distribution system.
6. True All excavation work must at all times be under the immediate supervision of someone with the authority to modify the shoring system as necessary to provide adequate safety.
7. True Contaminants can enter the water supplied to the distribution system through the source of the water supply.
8. True Improper chlorination in water treatment plants can cause tastes and odors in water delivered to consumers.
9. True Distribution systems should always be under a continuous positive pressure at all times.
10. False Distribution system reservoirs should be full at the start of the peak demand period.
11. False Cold water requires longer disinfection time than warm water.
12. False Chlorine gas used for disinfection tends to decrease the pH of water.
13. False Chlorine reacts with organic matter to form chlororganic compounds, including trihalomethanes.
14. True A cigarette can ignite hydrogen gas from the fluid in a battery.
15. True Before attempting to work on electrical motors, be sure to lock out and tag all electrical switches.

Multiple Choice

1. 1,4,5 Responsibilities of water distribution system operators include being sure adequate amounts of water and pressure are available, delivering safe and pleasant drinking water, and making facilities do their job. Building and designing are not operator's responsibilities.
2. 1,3,4,5 Abnormal conditions encountered by operators of water storage facilities include broken mains, fire demands, out-of-service pumps and stale water.
3. 1,2,3,4 Problems caused by freezing conditions in elevated tanks include damage to walls, depth sensors (floats) damaged, interior coating failure and interior ladders distorted.
4. 2,3,4,5 Water hammer can be caused by pumps suddenly starting or stopping and valves quickly closing or opening.
5. 2,4,5 Steel pipe may be lined with bituminous material, cement mortar and epoxy.
6. 1,2,3,4,5 Shoring requirements depend on depth of trench, laws and regulations, nearby activities, soil conditions and width of trench.
7. 1,3,4,5 Physical qualities of water important to consumers include color, odor, taste and temperature. Hardness is an important chemical quality.
8. 2,3,4,5 Elements of a water distribution system surveillance program include appearance of stored water, evidence of unauthorized entrance to facilities, storm damage and vandalism.
9. 1,2,4,5 Samples are routinely collected from water distribution systems and tested for chlorine residuals, coliform bacteria, tastes, odors and turbidity.
10. 1,2,5 Inaccurate meter registration results from corrosion, deposition and wear.
11. 1,4 Inorganic reducing compounds found in source waters that react rapidly with chlorine include ammonia and hydrogen sulfide.
12. 1,4,5 Precautions that should be taken when shutting down a hypochlorinator for a short duration include locking out circuits, turning off hypochlorinator and turning off water supply pump.
13. 1,4 Important aspects of a safety program include conducting regular safety programs and making operators aware of unsafe acts.
14. 1,2 Good safety practices for operators using boats include annual safety inspection and flotation device for each occupant.
15. 1,3,4 Fires involving sodium or zinc should be extinguished by the use of fine dry soda ash, graphite or sand.

Short Answers

1. Water supply system operators keep the system operating efficiently to deliver safe and pleasant water. They inspect the system to keep the water flowing today and in the future. Physically, they have manual and power-operated equipment to help them do the job, including repairs and minor additions to the system. Other jobs include lubricating and maintaining equipment, collecting water samples, and recordkeeping.

2. The major sources of contaminants in a water distribution system include the source of supply, the water treatment plant and factors within the distribution system, including the mains and storage facilities. Major sources in the distribution system include cross-connections, corrosion, biological growth and activity, and age of facilities.

3. Water treatment plants can cause water quality problems in a distribution system by:

   1. Breakdown of equipment,
   2. Chlorination of water containing organic materials which may result in the formation of trihalomethanes,
   3. Improper chlorination causing tastes and odors,
   4. Overdosing during coagulation treatment and causing turbidity and deposits, and
   5. Excessive use of manganese compounds for taste- and odor-control which cause colored water.

4. Operators should become certified because it is evidence of the operator's level of knowledge and proficiency on the job.

5. The advantages of distribution system water storage include:

   1. Demands on the source of water, the pumping facilities, and the transmission and distribution mains are more nearly equalized and also the capabilities of the tanks and other treatment facilities need not be so great.
   2. System flows and pressures are improved and stabilized.
   3. Reserve water supplies are provided in the distribution system for emergencies such as fire fighting and power outages.

6. The major disadvantages of using concrete pipe for water distribution system mains are that the pipe is heavy, may be hard to tap, needs special fittings and may deteriorate in aggressive (corrosive) soils.

7. Buried utilities that must be located BEFORE excavating include all water, sewer, gas, power, telephone and cable TV lines, and storm drains in the area.

8. Field crews should be on the lookout for any unauthorized construction activities which could damage the water distribution system, especially the buried pipe.

9. Water utilities can avoid serious valve problems by a comprehensive program of valve inspecting, exercising, and maintenance.

10. A work order system provides a systematic method of doing and recording all additions or changes to, or removal of, any of the system facilities.

11. Water mains can be kept clean during construction and repair by keeping material such as dirt, construction materials, animals, rodents and dirty water out of mains. Inspecting the pipes when laid, keeping trenches dry and installing watertight plugs all help to keep pipes clean.

12. Typical locations where a water utility operator should monitor atmospheric conditions before entry include underground regulator vaults, solution vaults, valve

boxes, manholes, elevated tanks, covered tanks, underground tanks, and all other confined spaces.

13. The job of the standby person outside a confined space work area is to check continuously on the status of personnel working in the confined space. Should a person working in the confined space be rendered unconscious due to asphyxiation or lack of oxygen, the standby at the surface could enter into the space by:
    1. Securing a back up rescue person, and
    2. Putting on the correct type of respiratory protective equipment.
14. A safety inspection of a fixed ladder should include checking for:
    1. Loose, worn and damaged rungs on side rails,
    2. Corroded or damaged parts of the security door,
    3. Corroded bolts or rivet heads where ladder is affixed to tank, and
    4. Defects in climbing devices, including loose or damaged carrier rails or cables.
15. Breakpoint chlorination is the addition of chlorine to water until the chlorine demand has been satisfied and further additions of chlorine result in a free available residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

Problems

1. Convert a flow of 300 GPM to MGD.

Known	Unknown
Flow, GPM = 300 GPM	Flow, MGD

Convert the flow of 300 GPM to MGD.

$$\text{Flow, MGD} = \frac{(\text{Flow, GPM})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000/\text{M}}$$

$$= \frac{(300\ \text{GPM})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000/\text{M}}$$

$$= 0.43\ \text{MGD}$$

2. Convert a flow of 60 GPD to milliliters per minute.

Known	Unknown
Flow, GPD = 60 GPD	Flow, m*L*/min

Convert flow from 60 GPD to milliliters per minute.

$$\text{Flow, m}L\text{/min} = \frac{(\text{Flow, GPD}(3.785\ L\text{/gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= \frac{(60\ \text{gal/day})(3.785\ L\text{/gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= 158\ \text{m}L\text{/min}$$

3. Convert a flow of 100 m*L*/min to GPD.

Known	Unknown
Flow, m*L*/.min = 100 m*L*/min	Flow, GPD

Convert 100 m*L*/min to GPD.

$$\text{Flow, GPD} = \frac{(\text{Flow, m}L\text{/min})(60\ \text{min/hr})(24\ \text{hr/day})}{(1000\ \text{m}L/L)(3.785\ L\text{/gal})}$$

$$= \frac{(100\ \text{m}L\text{/min})(60\ \text{min/hr})(24\ \text{hr/day})}{(1000\ \text{m}L/L)(3.785\ L\text{/gal})}$$

$$= 38\ \text{GPD}$$

4. Determine chlorinator setting in pounds per 24 hours to treat a flow of 0.90 MGD with a chlorine dose of 2.5 mg/*L*.

Known		Unknown
Flow, MGD	0.90 MGD	Chlorinator Setting, lbs/24 hours
Chlorine Dose, mg/*L*	= 2.5 mg/*L*	

Determine the chlorinator setting in pounds per 24 hours or pounds per day.

$$\text{Chemical Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.90\ \text{MGD})(2.5\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 19\ \text{lbs/day}$$

5. Calculate the volume of water in gallons in a rectangular storage tank 30 feet long, 12 feet wide and the water is 6 feet deep.

Known	Unknown
Length, ft = 30 ft	Tank Vol, gal
Width, ft = 12 ft	
Depth, ft = 6 ft	

Calculate the tank volume in gallons.

$$\text{Tank Vol, gal} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$= (30\ \text{ft})(12\ \text{ft})(6\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 16{,}157\ \text{gallons}$$

6. Calculate the volume of water in gallons in a circular storage tank 25 feet in diameter when the water is 8 feet deep.

Known	Unknown
Diameter, ft = 25 ft	Tank Vol, gal
Depth, ft = 8 ft	

Calculate the tank volume in gallons.

$$\text{Tank Vol, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(25\ \text{ft})^2(8\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 29{,}359\ \text{gallons}$$

7. Water is 29-feet deep in a water storage tank. What is the water pressure on the bottom of the tank in psi?

Known	Unknown
Depth, ft = 29 ft	Pressure, psi

Calculate the water pressure at the bottom of the tank in psi.

$$\text{Pressure, psi} = \frac{\text{Depth, ft}}{2.31\ \text{ft/psi}}$$

$$= \frac{29\ \text{ft}}{2.31\ \text{ft/psi}}$$

$$= 12.6\ \text{psi}$$

OR

Pressure, psi = (Depth, ft)(0.433 psi/ft)

= (29 ft)(0.433 psi/ft)

= 12.6 psi

8. The discharge pressure gage on a pump reads 43 psi. What is the discharge pressure head in feet?

Known	Unknown
Pressure, psi = 43 psi	Pressure Head, ft

Calculate the discharge pressure head in feet.

Pressure, ft = (Pressure, psi)(2.31 ft/psi)

= (43 psi)(2.31 ft/psi)

= 99 ft

OR

$$\text{Pressure, ft} = \frac{\text{Pressure, psi}}{0.433\ \text{psi/ft}}$$

$$= \frac{43\ \text{psi}}{0.433\ \text{psi/ft}}$$

= 99 ft

9. Convert a flow rate of three cubic feet per second to gallons per minute.

Known	Unknown
Flow, CFS = 3 CFS	Flow, GPM

Convert the flow from CFS to GPM.

Flow, GPM = (Flow, cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= (3 cu ft/sec)(7.48 gal/cu ft)(60 sec/min)

= 1346 GPM

10. Convert a flow rate of 300 gallons per minute to cubic feet per second.

Known	Unknown
Flow, GPM = 300 GPM	Flow, CFS

Convert the flow from GPM to CFS.

$$\text{Flow, CFS} = \frac{\text{Flow, gal/min}}{(7.48\ \text{gal/cu ft})(60\ \text{sec/min})}$$

$$= \frac{300\ \text{gal/min}}{(7.48\ \text{gal/cu ft})(60\ \text{sec/min})}$$

= 0.67 CFS

11. Calculate the flow in cubic feet per second in a 15-inch diameter pipe when the velocity is 2.4 feet per second.

Known	Unknown
Diameter, in = 15 in	Flow, CFS
Velocity, ft/sec = 2.4 ft/sec	

1. Calculate the area of the pipe in square feet.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144\ \text{sq in/sq ft}}$$

$$= \frac{(0.785)(15\ \text{in})^2}{144\ \text{sq in/sq ft}}$$

= 1.23 sq ft

2. Calculate the flow in cubic feet per second.

Flow Rate, CFS = (Area, sq ft)(Velocity, ft/sec)

= (1.23 sq ft)(2.4 ft/sec)

= 2.95 cubic feet/sec

12. A six-inch water line is to be flushed at a velocity of five feet per second. What should be the reading on the flow meter in gallons per minute?

Known	Unknown
Diameter, in = 6 in	Flow, GPM
Velocity, ft/sec = 5 ft/sec	

1. Calculate the cross-sectional area of the pipe in square feet.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144\ \text{sq in/sq ft}}$$

$$= \frac{(0.785)(6\ \text{in})^2}{144\ \text{sq in/sq ft}}$$

= 0.196 sq ft

2. Determine the flow in the pipe in cubic feet per second.

Flow, CFS = (Area, sq ft)(Velocity, ft/sec)

= (0.196 sq ft)(5 ft/sec)

= 0.98 CFS

3. Calculate the flow meter reading in gallons per minute (GPM).

Flow, GPM = (Flow, CFS)(7.48 gal/cu ft)(60 sec/min)

= (0.98 CFS)(7.48 gal/cu ft)(60 sec/min)

= 440 GPM

13. Estimate the flow in gallons per minute from a pump if a 750 gallon tank fills in three minutes.

Known	Unknown
Volume, gal = 750 gal	Flow, GPM
Time, min = 3 min	

Calculate the flow in gallons per minute.

$$\text{Flow, GPM} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$= \frac{750\ \text{gal}}{3\ \text{min}}$$

= 250 GPM

14. A water meter is tested in a laboratory. The meter read 195 gallons. The actual flow was measured in a volumetric tank as 197 gallons. Determine the meter accuracy as a percentage.

Known	Unknown
Meter Reading, gal = 195 gal	Meter Accuracy, %
Actual Volume, gal = 197 gal	

Determine the meter accuracy as a percentage.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, gal})(100\%)}{\text{Actual Volume, gal}}$$

$$= \frac{(195\ \text{gal})(100\%)}{197\ \text{gal}}$$

= 99.0%

15. A trench four-feet wide, 390-feet long and 6.3-feet deep is to be excavated for a water main. How many cubic yards of soil must be excavated for the water main?

Known		Unknown
Length, ft	= 390 ft	Volume Excavated, cu yds
Width, ft	= 4 ft	
Depth, ft	= 6.3 ft	

1. Calculate the volume to be excavated in cubic feet.

$$\text{Volume, cu ft} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})$$
$$= (390\text{ ft})(4\text{ ft})(6.3\text{ ft})$$
$$= 9828\text{ cu ft}$$

2. Calculate the volume excavated in cubic yards.

$$\text{Volume, cu yd} = \frac{\text{Volume, cu ft}}{27\text{ cu ft/cu yd}}$$
$$= \frac{9828\text{ cu ft}}{27\text{ cu ft/cu yd}}$$
$$= 364\text{ cu yd}$$

16. A flow meter indicates a flow of 90 GPM. How long will it take to fill a 16,200 gallon storage tank?

Known		Unknown
Flow Rate, GPM	= 90 GPM	Time to Fill, hr
Tank Volume, gal	= 16,200 gal	

Calculate the time to fill the storage tank.

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$
$$= \frac{16{,}200\text{ gal}}{90\text{ gal/min}}$$
$$= 180\text{ min}$$
$$\text{Time to Fill, hr} = \frac{180\text{ min}}{60\text{ min/hr}}$$
$$= 3\text{ hr}$$

17. What should be the chlorine dose of a water that has a chlorine demand of 1.3 mg/*L* if a residual of 0.4 mg/*L* is desired?

Known		Unknown
Chlorine Demand, mg/*L*	= 1.3 mg/*L*	Chlorine Dose, mg/*L*
Chlorine Residual, mg/*L*	= 0.4 mg/*L*	

Calculate the chlorine dose in milligrams per liter.

$$\text{Chlorine Dose, mg}/L = \text{Chlorine Demand, mg}/L + \text{Chlorine Residual, mg}/L$$
$$= 1.3\text{ mg}/L + 0.4\text{ mg}/L$$
$$= 1.7\text{ mg}/L$$

18. What should be the setting on a chlorinator in pounds per 24 hours if a pump usually delivers approximately 520 gallons per minute and the desired chlorine dose is 2.5 mg/*L*?

Known		Unknown
Pump Flow, GPM	= 520 GPM	Chlorinator Setting, lbs Chlorine/24 hrs
Chlorine, Dose, mg/*L*	= 2.5 mg/*L*	

1. Convert the flow from GPM to MGD.

$$\text{Flow, MGD} = \frac{(\text{Flow, GPM})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000/\text{M}}$$
$$= \frac{(520\text{ GPM})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000/\text{M}}$$
$$= 0.75\text{ MGD}$$

2. Calculate the chlorinator setting in pounds per 24 hours.

$$\text{Chlorinator Setting, lbs/24 hrs} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$
$$= (0.75\text{ MGD})(2.5\text{ mg}/L)(8.34\text{ lbs/gal})$$
$$= 16\text{ lbs/24 hrs}$$

19. Estimate the desired strength (as a percent chlorine) of a hypochlorite solution being pumped by a hypochlorinator that delivers 100 gallons per day. The water being treated requires a chlorine feed rate of 19 pounds of chlorine per day.

Known		Unknown
Hypochlorinator Flow, GPD	= 100 GPD	Hypochlorite Strength, %
Chlorine Required, lbs/day	= 19 lbs/day	

Estimate the desired hypochlorite strength as a percent chlorine.

$$\text{Hypochlorite Strength, \%} = \frac{(\text{Chlorine Required, lbs/day})(100\%)}{(\text{Hypochlorinator Flow, GPD})(8.34\text{ lbs/gal})}$$
$$= \frac{(19\text{ lbs/day})(100\%)}{(100\text{ gal/day})(8.34\text{ lbs/gal})}$$
$$= 2.3\%$$

20. A water treatment plant has seventeen 150-pound chlorine cylinders in storage. The plant uses an average of 127 pounds of chlorine per day. How many days' supply of chlorine is in storage?

Known		Unknown
Chlorine Cylinders	= 17 cylinders	Supply of Chlorine, days
Cylinders Wt, lbs/cyl	= 150 lbs/cyl	
Ave Use, lbs/day	= 127 lbs/day	

$$\text{Supply of Chlorine, days} = \frac{(\text{Cylinder Wt, lbs/cyl})(\text{No. of cylinders})}{\text{Ave Use, lbs/day}}$$
$$= \frac{(150\text{ lbs/cyl})(17\text{ cylinders})}{127\text{ lbs/day}}$$
$$= 20\text{ days}$$

APPENDIX

HOW TO SOLVE WATER DISTRIBUTION SYSTEM ARITHMETIC PROBLEMS

by

Ken Kerri

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OBJECTIVES

HOW TO SOLVE WATER DISTRIBUTION ARITHMETIC PROBLEMS

After completion of this Appendix, you should be able to do the following:

1. Add, subtract, multiply and divide.
2. List from memory basic conversion factors and formulas, and
3. Solve water distribution system arithmetic problems.

APPENDIX. HOW TO SOLVE WATER DISTRIBUTION SYSTEM ARITHMETIC PROBLEMS

A.0 HOW TO STUDY THIS APPENDIX

This appendix may be worked early in your training program to help you gain the greatest benefit from your efforts. Whether to start this appendix early or wait until later is your decision. The chapters in this manual were written in a manner requiring very little background in arithmetic. You may wish to concentrate your efforts on the chapters and refer to this appendix when you need help. Some operators prefer to complete this appendix early so they will not have to worry about how to do the arithmetic when they are studying the chapters. You may try to work this appendix early or refer to it while studying the other chapters.

The intent of this appendix is to provide you with a quick review of the addition, subtraction, multiplication and division needed to work the arithmetic problems in this manual. This appendix is not intended to be a math textbook. There are no fractions because you don't need fractions to work the problems in this manual. Some operators will be able to skip over the review of addition, subtraction, multiplication and division. Others may need more help in these areas. If you need help in solving problems, read Section A.9, "Steps in Solving Problems." Basic arithmetic textbooks are available at every local library or bookstore and should be referred to if needed. Most instructional or operating manuals for pocket electronic calculators contain sufficient information on how to add, subtract, multiply, and divide.

After you have worked a problem involving your job, you should check your calculations, examine your answer to see if it appears reasonable, and if possible have another operator check your work before making any decisions or changes.

A.1 BASIC ARITHMETIC

In this Section we are going to provide you with basic arithmetic problems involving addition, subtraction, multiplication and division. You may work the problems "by hand" if you wish, but we recommend you use an electronic pocket calculator. The operating or instructional manual for your calculator should outline the step-by-step procedures to follow. All calculators use similar procedures, but most of them are slightly different from others.

We will start with very basic, simple problems. Try working the problems and then comparing your answers with the given answers. If you can work these problems, you should be able to work the more difficult problems in the text of this training manual by using the same procedures.

A.10 Addition

2	6.2	16.7	6.12	43
3	8.5	38.9	38.39	39
5	14.	55.6	44.51	34
				38
				39
2.12	0.12	63	120	37
9.80	2.0	32	60	29
11.92	2.12	95	180	259
4	23	16.2	45.98	70
7	79	43.5	28.09	50
2	31	67.8	114.00	40
13	133	127.5	188.07	80
				240

A.11 Subtraction

7	12	25	78	83
−5	− 3	− 5	−30	−69
2	9	20	48	14
61	485	4.3	3.5	123
−37	−296	−0.8	−0.7	−109
24	189	3.5	2.8	− 14
8.6	11.92	27.32	3.574	75.132
−8.22	− 3.70	−12.96	−0.042	−49.876
0.38	8.22	14.36	3.532	25.256

A.12 Multiplication

(3)(2)[a] = 6 (4)(7) = 28

(10)(5) = 50 (10)(1.3) = 13

(2)(22.99) = 45.98 (6)(19.5) = 117

(16)(17.1) = 273.6 (50)(20,000) = 1,000,000

(40)(2.31) = 92.4 (80)(0.433) = 34.6

(40)(20)(6) = 4,800

(4,800)(7.48) = 35,904

(1.6)(2.3)(8.34) = 30.6912

(0.001)(200)(8.34) = 1.668

(0.785)(7.48)(60) = 352.308

(12,000)(500)(60)(24) = 8,640,000,000 or 8.64×10^9

(4)(1000)(1000)(454) = 1,816,000,000 or 1.816×10^9

NOTE: The term, $\times 10^9$, means that the number is multiplied by 10^9 or 1,000,000,000. Therefore 8.64×10^9 = $8.64 \times$ 1,000,000,000 = 8,640,000,000.

---

[a] (3)(2) is the same as 3 × 2 = 6.

A.13 Division

$$\frac{6}{3} = 2$$

$$\frac{50}{25} = 2$$

$$\frac{20}{7.1} = 2.8$$

$$\frac{1{,}000{,}000}{17.5} = 57{,}143$$

$$\frac{4{,}000{,}000}{74{,}880} = 53.4$$

$$\frac{80}{2.31} = 34.6$$

$$\frac{250}{17.1} = 14.6$$

$$\frac{48}{12} = 4$$

$$\frac{300}{20} = 15$$

$$\frac{11{,}400}{188} = 60.6$$

$$\frac{861{,}429}{30{,}000} = 28.7$$

$$\frac{1.67}{8.34} = 0.20$$

$$\frac{62}{454} = 0.137$$

$$\frac{4{,}000{,}000}{14.6} = 273{,}973$$

NOTE: When we divide 1/3 = 0.3333, we get a long row of 3s. Instead of the row of 3s, we "round-off" our answer so 1/3 = 0.33. For a discussion of rounding off numbers, see Section A.95, "Significant Figures."

A.14 Multiplication and Division

Many of the problems we work in the waterworks field involve both multiplication and division. Sometimes addition or subtraction is also involved. To work these types of problems:

1. Do all the addition and subtraction above and below the line,
2. Do all the multiplication above and below the line, and
3. Perform the division.

Instructions for your electronic calculator can provide you with the detailed procedures.

$$\frac{(3)(4)}{2} = 6$$

$$\frac{(2+3)(4)}{5} = 4$$

$$\frac{(7-2)(8)}{4} = 10$$

$$\frac{(9)(8)-(6)(6)}{3} = 12$$

$$\frac{(20)}{(0.85)(8.34)} = 2.82$$

$$\frac{(14)(2)}{(13.53-12.98)(8.34)} = 6.10$$

$$\frac{(13)(100)}{(120)(8.34)} = 1.3$$

$$\frac{861{,}429}{(500)(60)} = 28.7$$

$$\frac{64}{(8)(4)} = 2$$

$$\frac{(54)}{(4+2)(3)} = 3$$

$$\frac{48}{(8-3)(4)} = 2.4$$

$$\frac{(16)(6)}{(8)(7)-(4)(4)} = 2.4$$

$$\frac{30-27}{(1.6)(8.34)} = 0.22$$

$$\frac{(4)(1{,}000{,}000)}{74{,}880} = 53.4$$

$$\frac{(0.1)(60)(24)}{3} = 48$$

$$\frac{(12{,}000)(500)(60)(24)}{(4)(1000)(1000)(454)} = 4.76$$

$$\frac{12}{(0.432)(8.34)} = 3.3$$

$$\frac{(274{,}000)(24)}{200{,}000} = 32.88$$

A.15 Actual Problems

Let's look at the last four problems in the previous Section A.14, "Multiplication and Division," as they might be encountered by an operator.

1. To determine the actual chemical feed rate from an alum feeder, an operator collects the alum from the feeder in a bucket for three minutes. The alum in the bucket weighs 0.1 pounds.

Known		Unknown
Weight of Alum, lbs	= 0.1 lbs	Actual Alum Feed, lbs/day
Time, min	= 3 min	

Calculate the actual alum feed rate in pounds per day.

$$\text{Actual Alum Feed Rate, lbs/day} = \frac{(\text{Alum Wt, lbs})(60\ \text{min/hr})(24\ \text{hr/day})}{\text{Time Alum Collected, min}}$$

$$= \frac{(0.1\ \text{lbs})(60\ \text{min/hr})(24\ \text{hr/day})}{3\ \text{min}}$$

$$= 48\ \text{lbs/day}$$

2. A solution chemical feeder is calibrated by measuring the time to feed 500 milliliters of chemical solution. The test calibration run required four minutes. The chemical concentration in the solution is 12,000 mg/*L* or 1.2%. Determine the chemical feed in pounds per day.

Known		Unknown
Volume Pumped, m*L*	= 500 m*L*	Chemical Feed, lbs/day
Time Pumped, min	= 4 min	
Chemical Conc., mg/*L*	= 12,000 mg/*L*	

Estimate the chemical feed rate in pounds per day.

$$\text{Chemical Feed, lbs/day} = \frac{(\text{Chem Conc, mg}/L)(\text{Vol Pumped, m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(\text{Time Pumped, min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(454\ \text{gm/lb})}$$

$$= \frac{(12{,}000\ \text{mg}/L)(500\ \text{m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(4\ \text{min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(454\ \text{gm/lb})}$$

$$= 4.76\ \text{lbs/day}$$

3. A chlorinator is set to feed twelve pounds of chlorine per day to a flow of 300 gallons per minute (0.432 million gallons per day). What is the chlorine dose in milligrams per liter?

Known		Unknown
Chlorinator Feed, lbs/day	= 12 lbs/day	Chlorine Dose, mg/*L*
Flow, MGD	= 0.432 MGD	

Determine the chlorine dose in milligrams per liter.

$$\text{Chlorine Dose, mg}/L = \frac{\text{Chlorinator Feed Rate, lbs/day}}{(\text{Flow, MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{12\text{ lbs/day}}{(0.432\text{ MGD})(8.34\text{ lbs/gal})}$$

$$= 3.3\text{ mg}/L$$

4. Estimate the operating time of a water softening ion exchange unit before the unit needs regeneration. The unit can treat 274,000 gallons of water before the exchange capacity is exhausted. The average daily flow is 200,000 gallons per day.

Known		Unknown
Water Treated, gal	= 274,000 gal	Operating Time, hr
Ave Daily Flow, gal/day	= 200,000 gal/day	

Estimate the operating time of the ion exchange unit in hours.

$$\text{Operating Time, hr} = \frac{(\text{Water Treated, gal})(24\text{ hr/day})}{\text{Ave Daily Flow, gal/day}}$$

$$= \frac{(274{,}000\text{ gal})(24\text{ hr/day})}{200{,}000\text{ gal/day}}$$

$$= 32.9^{*}\text{ hours}$$

---

*We rounded off 32.88 hours to 32.9 hours.

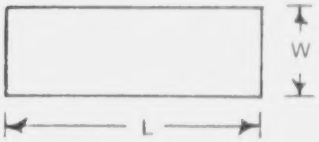
A.2 AREAS

A.20 Units

Areas are measured in two dimensions or in square units. In the English system of measurement the most common units are square inches, square feet, square yards, and square miles. In the metric system the units are square millimeters, square centimeters, square meters, and square kilometers.

A.21 Rectangle

The area of a rectangle is equal to its length (L) multiplied by its width (W).



A = L × W

Example: Find the area of a rectangle if the length is 5 feet and the width is 3.5 feet.

$$\text{Area, sq ft} = \text{Length, ft} \times \text{Width, ft}$$

$$= 5\text{ ft} \times 3.5\text{ ft}$$

$$= 17.5\text{ ft}^2$$

$$= 17.5\text{ sq ft}$$

Example: The surface area of a settling basin is 330 square feeet. One side measures 15 feet. How long is the other side?

$$A = L \times W$$

$$330\text{ sq ft} = L\text{ ft} \times 15\text{ ft}$$

$$\frac{L\text{ ft} \times 15\text{ ft}}{15\text{ ft}} = \frac{330\text{ ft}^2}{15\text{ ft}}$$ Divide both sides of equation by 15 ft.

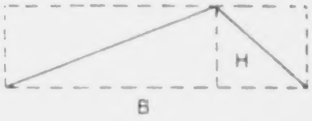
$$L\text{ ft} = \frac{330\text{ ft}^2}{15\text{ ft}}$$

$$= 22\text{ ft}$$

A.22 Triangle

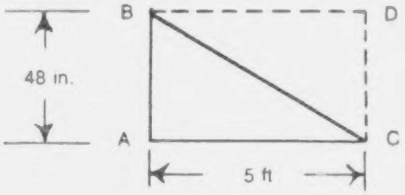
The area of a triangle is equal to one half the base multiplied by the height. This is true for any triangle.

A = ½ B × H



NOTE: The area of *ANY* triangle is equal to ½ the area of the rectangle that can be drawn around it. The area of the rectangle is B × H. The area of the triangle is ½ B × H.

Example: Find the area of triangle ABC.



The first step in the solution is to make all the units the same. In this case, it is easier to change inches to feet.

$$48\,\cancel{\text{in}} = 48\text{ in} \times \frac{1\text{ ft}}{12\,\cancel{\text{in}}} = \frac{48}{12}\text{ ft} = 4\text{ ft}$$

NOTE: All conversions should be calculated in the above manner. Since 1 ft/12 in is equal to unity, or one, multiplying by this factor changes the form of the answer but not its value.

$$\text{Area, sq ft} = \tfrac{1}{2}\,(\text{Base, ft})(\text{Height, ft})$$

$$= \tfrac{1}{2} \times 5\text{ ft} \times 4\text{ ft}$$

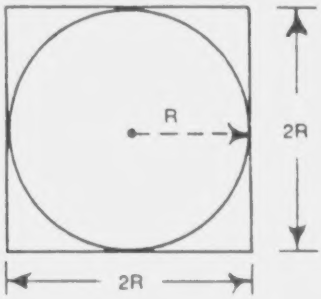
$$= \frac{20}{2}\text{ ft}^2$$

$$= 10\text{ sq ft}$$

NOTE: Triangle ABC is one half the area of rectangle ABCD. The triangle is a special form called a *RIGHT TRIANGLE* since it contains a 90° angle at point A.

A.23 Circle

A square with sides of 2R can be drawn around a circle with a radius of R.



The area of the square is: $A = 2R \times 2R = 4R^2$.

It has been found that the area of any circle inscribed within a square is slightly more than ¾ of the area of the square. More precisely, the area of the preceding circle is:

$$A \text{ circle} = 3\frac{1}{7}R^2 = 3.14\ R^2$$

The formula for the area of a circle is usually written:

$$\boxed{A = \pi R^2}$$

The Greek letter π (pronounced pie) merely substitutes for the value 3.1416.

Since the diameter of any circle is equal to twice the radius, the formula for the area of a circle can be rewritten as follows:

$$A = \pi R^2 = \pi \cdot R \cdot R = \pi \cdot \frac{D}{2} \cdot \frac{D}{2} = \frac{\pi D^2}{4} = \frac{3.14}{4} D^2 = \boxed{0.785\ D^2}$$

The type of problem and the magnitude of the numbers in a problem will determine which of the two formulas will provide a simpler solution. All of these formulas will give the same results if you use the same number of digits to the right of the decimal point.

Example: What is the area of a circle with a diameter of 20 centimeters?

In this case, the formula using a radius is more convenient since it takes advantage of multiplying by 10.

$$\begin{aligned}\text{Area, sq cm} &= \pi\ (\text{R, cm})^2\\ &= 3.14 \times 10\text{ cm} \times 10\text{ cm}\\ &= 314\text{ sq cm}\end{aligned}$$

Example: What is the area of a clarifier with a 50-foot radius?

In this case, the formula using diameter is more convenient.

$$\begin{aligned}\text{Area, sq ft} &= 0.785\ (\text{Diameter, ft})^2\\ &= 0.785 \times 100\text{ ft} \times 100\text{ ft}\\ &= 7850\text{ sq ft}\end{aligned}$$

Occasionally the operator may be confronted with a problem giving the area and requesting the radius or diameter. This presents the special problem of finding the square root of the number.

Example: The surface area of a circular clarifier is approximately 5000 square feet. What is the diameter?

$A = 0.785\ D^2$, or

$\text{Area, sq ft} = 0.785\ (\text{Diameter, ft})^2$

$5000\text{ sq ft} = 0.785\ D^2$ — To solve, substitute given values in equation.

$\frac{0.785\ D^2}{0.785} = \frac{5000\text{ sq ft}}{0.785}$ — Divide both sides by 0.785 to find D^2

$$\begin{aligned}D^2 &= \frac{5000\text{ sq ft}}{0.785}\\ &= 6369\text{ sq ft. Therefore,}\end{aligned}$$

$D = \text{square root of } 6369\text{ sq ft, or}$

$\text{Diameter, ft} = \sqrt{6369\text{ sq ft}}$

Punch the $\sqrt{\ }$ sign on your calculator and get
D ft = 79.8 ft.

Sometimes it is easier to use a trial and error method of finding square roots. Since $80 \times 80 = 6400$, we know the answer is close to 80 feet.

Try $79 \times 79 = 6241$

Try $79.5 \times 79.5 = 6320.25$

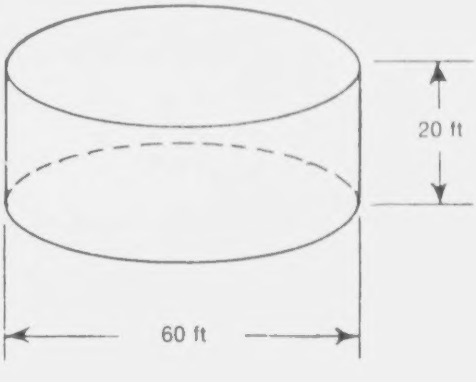
Try $79.8 \times 79.8 = 6368.04$

The diameter is 79.8 ft, or approximately 80 feet.

A.24 Cylinder

With the formulas presented thus far, it would be a simple matter to find the number of square feet in a room that was to be painted. The length of each wall would be added together and then multiplied by the height of the wall. This would give the surface area of the walls (minus any area for doors and windows). The ceiling area would be found by multiplying length times width and the result added to the wall area gives the total area.

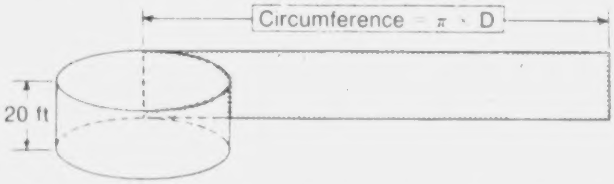
The surface area of a circular cylinder, however, has not been discussed. If we wanted to know how many square feet of surface area are in a tank with a diameter of 60 feet and a height of 20 feet, we could start with the top and bottom.



The area of the top and bottom ends are both $\pi \times R^2$

Area, sq ft = 2 ends $(\pi)(\text{Radius, ft})^2$
= $2 \times \pi \times (30\ \text{ft})^2$
= 5652 sq ft

The surface area of the wall must now be calculated. If we made a vertical cut in the wall and unrolled it, the straightened wall would be the same length as the circumference of the floor and ceiling.



This length has been found to always be $\pi \times D$. In the case of the tank, the length of the wall would be:

Length, ft = (π) (Diameter, ft)
= 3.14 × 60 ft
= 188.4 ft

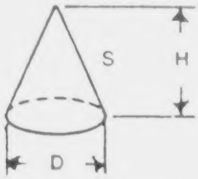
Area would be:

A_w sq ft = Length, ft × Height, ft
= 188.4 ft × 20 ft
= 3768 sq ft

Outside Surface Area to Paint, sq ft = Area of top and bottom, sq ft + Area of wall, sq ft
= 5652 sq ft + 3768 sq ft
= 9420 sq ft

A container has inside and outside surfaces and you may need to paint both of them.

A.25 Cone



The lateral area of a cone is equal to ½ of the slant height (S) multiplied by the circumference of the base.

$$\boxed{A_L = \tfrac{1}{2} S \times \pi \times D = \pi \times S \times R}$$

In this case the slant height is not given, it may be calculated by:

$S = \sqrt{R^2 + H^2}$

Example: Find the entire outside area of a cone with a diameter of 30 inches and a height of 20 inches.

Slant Height, in = $\sqrt{(\text{Radius, in})^2 + (\text{Height, in})^2}$
= $\sqrt{(15\ \text{in})^2 + (20\ \text{in})^2}$
= $\sqrt{225\ \text{in}^2 + 400\ \text{in}^2}$
= $\sqrt{625\ \text{in}^2}$
= 25 in

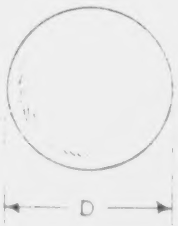
Area of Cone, sq in = π (Slant Height, in)(Radius, in)
= 3.14 × 25 in × 15 in
= 1177.5 sq in

Since the entire area was asked for, the area of the base must be added.

Area, sq in = 0.785 $(\text{Diameter, in})^2$
= 0.785 × 30 in × 30 in
= 706.5 sq in

Total Area, sq in = Area of Cone, sq in + Area of Bottom, sq in
= 1177.5 sq. in + 706.5 sq in
= 1884 sq in

A.26 Sphere



The surface area of a sphere or ball is equal to π multiplied by the diameter squared.

$$\boxed{A_S = \pi D^2}$$

If the radius is used, the formula becomes:

$A_S = \pi D^2 = \pi \times 2R \times 2R = 4\pi R^2$

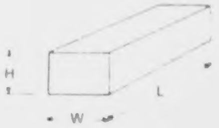
Example: What is the surface area of a sphere-shaped water tank 20 feet in diameter?

Area, sq ft = π $(\text{Diameter, ft})^2$
= 3.14 × 20 ft × 20 ft
= 1256 sq ft

A.3 VOLUMES

A.30 Rectangle

Volumes are measured in three dimensions or in cubic units. To calculate the volume of a rectangle, the area of the base is calculated in square units and then multiplied by the height. The formula then becomes:



$$\boxed{V = L \times W \times H}$$

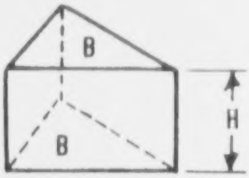
Example: The length of a box is two feet, the width is 15 inches, and the height is 18 inches. Find its volume.

$$\text{Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Height, ft}$$
$$= 2\text{ ft} \times \frac{15\text{ in}}{12\text{ in/ft}} \times \frac{18\text{ in}}{12\text{ in/ft}}$$
$$= 2\text{ ft} \times 1.25\text{ ft} \times 1.5\text{ ft}$$
$$= 3.75\text{ cu ft}$$

A.31 Prism

The same general rule that applies to the volume of a rectangle also applies to a prism.

$$\boxed{\text{Volume} = \text{Area of Base} \times \text{Height}}$$



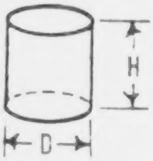
Example: Find the volume of a prism with a base area of 10 square feet and a height of 5 feet. (Note that the base of a prism is triangular in shape)

$$\text{Volume, cu ft} = \text{Area of Base, sq ft} \times \text{Height, ft}$$
$$= 10\text{ sq ft} \times 5\text{ ft}$$
$$= 50\text{ cu ft}$$

A.32 Cylinder

The volume of a cylinder is equal to the area of the base multiplied by the height.

$$\boxed{V = \pi R^2 \times H = 0.785\ D^2 \times H}$$



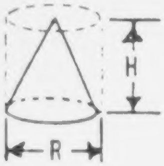
Example: A tank has a diameter of 100 feet and a depth of 12 feet. Find the volume.

$$\text{Volume, cu ft} = 0.785 \times (\text{Diameter, ft})^2 \times \text{Height, ft}$$
$$= 0.785 \times 100\text{ ft} \times 100\text{ ft} \times 12\text{ ft}$$
$$= 94{,}200\text{ cu ft}$$

A.33 Cone

The volume of a cone is equal to ⅓ the volume of a circular cylinder of the same height and diameter.

$$\boxed{V = \frac{\pi}{3} R^2 \times H}$$



Example: Calculate the additional volume in the cone portion of the tank in Section A.32 if the depth at the center of the tank is 16 ft. H = 16 ft − 12 ft.

$$\text{Volume, cu ft} = \frac{\pi}{3} \times (\text{Radius})^2 \times \text{Height, ft}$$
$$= \frac{\pi}{3} \times 50\text{ ft} \times 50\text{ ft} \times 4\text{ ft}$$
$$= 10{,}500\text{ cu ft}$$

A.34 Sphere

The volume of a sphere is equal to π/6 times the diameter cubed.

$$V = \frac{\pi}{6} \times D^3$$

Example: How much gas can be stored in a sphere with a diameter of 12 feet? (Assume atmospheric pressure.)

$$\text{Volume, cu ft} = \frac{\pi}{6} \times (\text{Diameter, ft})^3$$
$$= \frac{\pi}{\cancel{6}} \times \overset{2}{\cancel{12}}\text{ ft} \times 12\text{ ft} \times 12\text{ ft}$$
$$= 904.32\text{ cubic feet}$$

A.4 METRIC SYSTEM

The two most common systems of weights and measures are the English system and the Metric system. Of these two, the Metric system is more popular with most of the nations of the world. The reason for this is that the Metric system is based on a system of tens and is therefore easier to remember and easier to use than the English system. Even though the basic system in the United States is the English system, the scientific community uses the Metric system almost exclusively. Many organizations have urged, for good reason, that the United States switch to the Metric system. Today the Metric system is gradually becoming the standard system of measurement in the United States.

As the United States changes from the English to the Metric system, some confusion and controversy has developed. For example, which is the correct spelling of the following words:

1. Liter or litre?
2. Meter or metre?

The U.S. National Bureau of Standards, the Water Pollution Control Federation, and the American Water Works Association use litre and metre. The U.S. Government uses liter and meter and accepts no deviations. Some people argue that METRE should be used to measure LENGTH and that METER should be used to measure FLOW RATES (like a water or electric meter). Liter and Meter are used in this manual because this is most consistent with spelling in the United States.

One of the most frequent arguments heard against the U.S. switching to the Metric system was that the costs of switching manufacturing processes would be excessive. Pipe manufacturers have agreed upon the use of a "soft" metric conversion system during the conversion to the Metric system. Past practice in the U.S. has identified some types of pipe by external (outside) diameter while other types are classified by nominal (existing only in name, not real or actual) bore. This means that a six-inch pipe does not have a six-inch inside diameter. With the strict or "hard" metric system, a six-inch pipe would be a 152.4 mm (6 in × 25.4 mm/in) pipe. In the "soft" metric system a six-inch pipe is a 150 mm (6 in × 25 mm/in) pipe. Typical customary and "soft" metric pipe-size designations are shown below:

PIPE-SIZE DESIGNATIONS

Customary, in	2	4	6	8	10	12	15	18
"Soft" Metric, mm	50	100	150	200	250	300	375	450
Customary, in	24	30	36	42	48	60	72	84
"Soft" Metric, mm	600	750	900	1050	1200	1500	1800	2100

In order to study the Metric system, you must know the meanings of the terminology used. Following is a list of Greek and Latin prefixes used in the Metric system.

PREFIXES USED IN THE METRIC SYSTEM

Prefixes	Symbol	Meaning
Micro	μ	1/1 000 000 or 0.000 001
Milli	m	1/1000 or 0.001
Centi	c	1/100 or 0.01
Deci	d	1/10 or 0.1
Unit		1
Deka	da	10
Hecto	h	100
Kilo	k	1000
Mega	M	1 000 000

A.40 Measures of Length

The basic measure of length is the meter.

1 kilometer (km) = 1000 meters (m)
1 meter (m) = 100 centimeters (cm)
1 centimeter (cm) = 10 millimeters (mm)

Kilometers are usually used in place of miles, meters are used in place of feet and yards, centimeters are used in place of inches and millimeters are used for inches and fractions of an inch

LENGTH EQUIVALENTS

1 kilometer	= 0.621 mile	1 mile	= 1.61 kilometers
1 meter	= 3.28 feet	1 foot	= 0.305 meter
1 meter	= 39.37 inches	1 inch	= 0.0254 meter
1 centimeter	= 0.3937 inch	1 inch	= 2.54 centimeter
1 millimeter	= 0.0394 inch	1 inch	= 25.4 millimeters

NOTE: The above equivalents are reciprocals. If one equivalent is given, the reverse can be obtained by division. For instance, if one meter equals 3.28 feet, one foot equals 1/3.28 meter, or 0.305 meter.

A.41 Measures of Capacity or Volume

The basic measure of capacity in the Metric system is the liter. For measurement of large quantities the cubic meter is sometimes used.

1 kiloliter (k*L*) = 1000 liters (*L*) = 1 cu meter (m^3)

1 liter (*L*) = 1000 milliliters (m*L*)

Kiloliters, or cubic meters, are used to measure capacity of large storage tanks or reservoirs in place of cubic feet or gallons. Liters are used in place of gallons or quarts. Milliliters are used in place of quarts, pints, or ounces.

CAPACITY EQUIVALENTS

1 kiloliter	= 264.2 gallons	1 gallon	= 0.003785 kiloliter
1 liter	= 1.057 quarts	1 quart	= 0.946 liter
1 liter	= 0.2642 gallons	1 gallon	= 3.785 liters
1 milliliter	= 0.0353 ounce	1 ounce	= 28.35 milliliters

A.42 Measures of Weight

The basic unit of weight in the Metric system is the gram. One cubic centimeter of water at maximum density weighs one gram, and thus there is a direct, simple relation between volume of water and weight in the Metric system.

1 kilogram (kg) = 1000 grams (gm)
1 gram (gm) = 1000 milligrams (mg)
1 milligram (mg) = 1000 micrograms (μg)

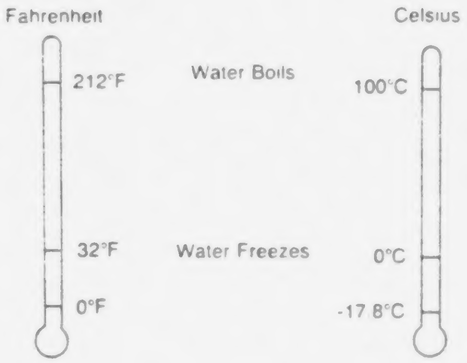
Grams are usually used in place of ounces, and kilograms are used in place of pounds.

WEIGHT EQUIVALENTS

1 kilogram	= 2.205 pounds	1 pound	= 0.4536 kilogram
1 gram	= 0.0022 pound	1 pound	= 453.6 grams
1 gram	= 0.0353 ounce	1 ounce	= 28.35 grams
1 gram	= 15.43 grains	1 grain	= 0.0648 gram

A.43 Temperature

Just as the operator should become familiar with the Metric system, you should also become familiar with the centigrade (Celsius) scale for measuring temperature. There is nothing magical about the centigrade scale — it is simply a different size than the Fahrenheit scale. The two scales compare as follows:



The two scales are related in the following manner:

Fahrenheit = (°C × 9/5) + 32°
Celsius = (°F − 32°) × 5/9

Example: Convert 20° Celsius to Fahrenheit

$$F = (°C \times 9/5) + 32°$$
$$F = (20° \times 9/5) + 32°$$
$$F = \frac{180°}{5} + 32°$$
$$= 36° + 32°$$
$$= 68°F$$

Example: Convert −10°C to °F.

$$F = (-10° \times 9/5) + 32°$$
$$F = -90°/5 + 32°$$
$$= -18° + 32°$$
$$= 14°F$$

Example: Convert −13°F to °C.

$$C = (°F - 32°) \cdot \frac{5}{9}$$

$$C = (-13° - 32°) \cdot \frac{5}{9}$$

$$= -45° \cdot \frac{5}{9}$$

$$= -5° \cdot 5$$

$$= -25°C$$

A.44 Milligrams per Liter

Milligrams per liter (mg/*L*) is a unit of measurement used in laboratory and scientific work to indicate very small concentrations of dilutions. Since water contains small concentrations of dissolved substances and solids, and since small amounts of chemical compounds are sometimes used in water treatment processes, the term milligrams per liter is also common in treatment plants. It is a weight/volume relationship.

As previously discussed:

1000 liters = 1 cubic meter = 1,000,000 cubic centimeters

Therefore

1 liter = 1000 cubic centimeters

Since one cubic centimeter of water weighs one gram,

1 liter of water = 1000 grams or 1,000,000 milligrams

$$\boxed{\frac{1\ \text{milligram}}{\text{liter}} = \frac{1\ \text{milligram}}{1{,}000{,}000\ \text{milligrams}} = \frac{1\ \text{part}}{\text{million parts}} = \text{1 part per million (ppm)}}$$

Milligrams per liter and parts per million (parts) may be used interchangeably as long as the liquid density is 1.0 gm/cu cm or 62.43 lb/cu ft. A concentration of 1 milligram/liter (mg/*L*) or 1 ppm means that there is 1 part of substance by weight for every 1 million parts of water. A concentration of 10 mg/*L* would mean 10 parts of substance per million parts of water.

To get an idea of how small 1 mg/*L* is, divide the numerator and denominator of the fraction by 10,000. This, of course, does not change its value since, 10,000 ÷ 10,000 is equal to one.

$$\boxed{1\,\frac{\text{mg}}{L} = \frac{1\ \text{mg}}{1{,}000{,}000\ \text{mg}} = \frac{1/10{,}000\ \text{mg}}{1{,}000{,}000/10{,}000\ \text{mg}} = \frac{0.0001\ \text{mg}}{100\ \text{mg}} = 0.0001\%}$$

Therefore, 1 mg/*L* is equal to one ten-thousandth of a percent, or

1% is equal to 10,000 mg/*L*

To convert mg/*L* to %, move the decimal point four places or numbers to the left.

Working problems using milligrams per liter or parts per million is a part of everyday operation in most water treatment plants.

A.45 Example Problems

Example: Raw water flowing into a plant at a rate of five million pounds per day is prechlorinated at 5 mg/*L*. How many pounds of chlorine are used per day?

$$5\ \text{mg}/L = \frac{5\ \text{lbs chlorine}}{\text{million lbs water}}$$

$$\text{Chlorine Feed, lbs/day} = \text{Concentration, lbs/M lbs} \times \text{Flow, lbs/day}$$

$$= \frac{5\ \text{lbs}}{\cancel{\text{million lbs}}} \times \frac{5\ \cancel{\text{million lbs}}}{\text{day}}$$

$$= 25\ \text{lbs/day}$$

There is one thing that is unusual about the above problem and that is the flow is reported in pounds per day. In most treatment plants, flow is reported in terms of gallons per minute or gallons per day. To convert these flow figures to weight, an additional conversion factor is needed. One gallon of water weighs 8.34 pounds. Using this factor, it is possible to convert flow in gallons per day to flow in pounds per day.

Example: A well pump with a flow of 3.5 million gallons per day (MGD) chlorinates the water with 2.0 mg/*L* chlorine. How many pounds of chlorine are used per day?

$$\text{Flow, lbs/day} = \text{Flow, }\frac{\text{M gal}}{\text{day}} \cdot 8.34\,\frac{\text{lb}}{\text{gal}}$$

$$= \frac{3.5\ \text{million}\ \cancel{\text{gal}}}{\text{day}} \times \frac{8.34\ \text{lbs}}{\cancel{\text{gal}}}$$

$$= 29.19\ \text{million lbs/day}$$

$$\text{Chlorine Feed, lbs/day} = \text{Level, mg}/L \cdot \text{Flow, M lb/day}$$

$$= \frac{2.0\ \cancel{\text{mg}}^{*}}{\cancel{\text{million mg}}} \times \frac{29.10\ \cancel{\text{million}}\ \text{lbs}}{\text{day}}$$

$$= 58.38\ \text{lbs/day}$$

---

* Remember that $\frac{1\ \text{mg}}{\text{M mg}} = \frac{1\ \text{lb}}{\text{M lb}}$. They are identical ratios.

In solving the above problem, a relation was used that is most important to understand and commit to memory.

$$\boxed{\text{Feed, lbs/day} = \text{Flow, MGD} \times \text{Dose, mg}/L \times 8.34\ \text{lbs/gal}}$$

Example: A chlorinator is set to feed 50 pounds of chlorine per day to a flow of 0.8 MGD. What is the chlorine dose in mg/*L*?

$$\text{Conc. or Dose, mg}/L = \frac{\text{lbs/day}}{\text{MGD} \times 8.34\ \text{lb/gal}}$$

$$= \frac{50\ \text{lb/day}}{0.80\ \text{MG/day} \times 8.34\ \text{lb/gal}}$$

$$= \frac{50\ \text{lb}}{6.672\ \text{M lb}}$$

$$= 7.5\ \text{mg}/L,\ \text{or}\ 7.5\ \text{ppm}$$

Example: A pump delivers 500 gallons per minute to a water treatment plant. Alum is added at 10 mg/*L*. How much alum is used in pounds per day?

$$\text{Flow, MGD} = \text{Flow, GPM} \times 60\ \text{min/hr} \times 24\ \text{hr/day}$$

$$= \frac{500\ \text{gal}}{\cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{\cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hr}}}{\text{day}}$$

$$= 720{,}000\ \text{gal/day}$$

$$= 0.72\ \text{MGD}$$

$$\text{Alum Feed, lbs/day} = \text{Flow, MGD} \times \text{Dose, mg/}L \times 8.34\ \text{lbs/gal}$$

$$= \frac{0.72\ \cancel{\text{M}}\ \cancel{\text{gal}}}{\text{day}} \times \frac{10\ \cancel{\text{mg}}}{\cancel{\text{M}}\ \cancel{\text{mg}}} \times \frac{8.34\ \text{lb}}{\cancel{\text{gal}}}$$

$$= 60.048\ \text{lbs/day or about } 60\ \text{lbs/day}$$

A.5 WEIGHT-VOLUME RELATIONS

Another factor for the operator to remember, in addition to the weight of a gallon of water, is the weight of a cubic foot of water. One cubic foot of water weighs 62.4 lbs. If these two weights are divided, it is possible to determine the number of gallons in a cubic foot.

$$\frac{62.4\ \cancel{\text{pounds}}/\text{cu ft}}{8.34\ \cancel{\text{pounds}}/\text{gal}} = 7.48\ \text{gal/cu ft}$$

Thus we have another very important relationship to commit to memory.

$$\boxed{8.34\ \text{lb/gal} \times 7.48\ \text{gal/cu ft} = 62.4\ \text{lb/cu ft}}$$

It is only necessary to remember two of the above items since the third may be found by calculation. For most problems, 8⅓ lbs/gal and 7½ gal/cu ft will provide sufficient accuracy.

Example: Change 1000 cu ft of water to gallons.

1000 cu ft × 7.48 gal/cu ft = 7480 gallons

Example: What is the weight of three cubic feet of water?

62.4 lb/cu ft × 3 cu ft = 187.2 lbs

Example: The net weight of a tank of water is 750 lbs. How many gallons does it contain?

$$\frac{750\ \cancel{\text{lb}}}{8.34\ \cancel{\text{lb}}/\text{gal}} = 90\ \text{gals}$$

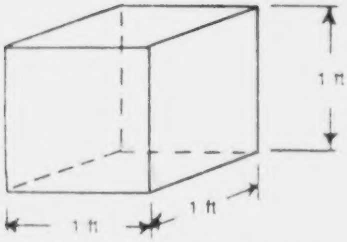
A.6 FORCE, PRESSURE, AND HEAD

In order to study the forces and pressures involved in fluid flow, it is first necessary to define the terms used.

FORCE:	The push exerted by water on any surface being used to confine it. Force is usually expressed in pounds, tons, grams, or kilograms.
PRESSURE:	The force per unit area. Pressure can be expressed in many ways, but the most common term is pounds per square inch (psi).
HEAD:	Vertical distance from the water surface to a reference point below the surface. Usually expressed in feet or meters.

An *EXAMPLE* should serve to illustrate these terms.

If water were poured into a one-foot cubical container, the *FORCE* acting on the bottom of the container would be 62.4 pounds.



The *PRESSURE* acting on the bottom would be 62.4 pounds per square foot. The area of the bottom is also 12 in × 12 in = 144 in². Therefore, the pressure may also be expressed as:

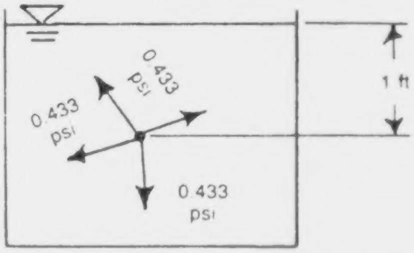
$$\text{Pressure, psi} = \frac{62.4\ \text{lb}}{\text{sq ft}} = \frac{62.4\ \text{lb/sq ft}}{144\ \text{sq in/sq ft}}$$

$$= 0.433\ \text{lb/sq in}$$

$$= 0.433\ \text{psi}$$

Since the height of the container is one foot, the *HEAD* would be one foot.

The pressure in any vessel at one foot of depth or one foot of head is 0.433 psi acting in any direction.



If the depth of water in the previous example were increased to two feet, the pressure would be:

$$p = \frac{2\ (62.4\ \text{lb})}{144\ \text{sq in}} = \frac{124.8\ \text{lb}}{144\ \text{sq in}} = 0.866\ \text{psi}$$

Therefore we can see that for every foot of head, the pressure increases by 0.433 psi. Thus, the general formula for pressure becomes:

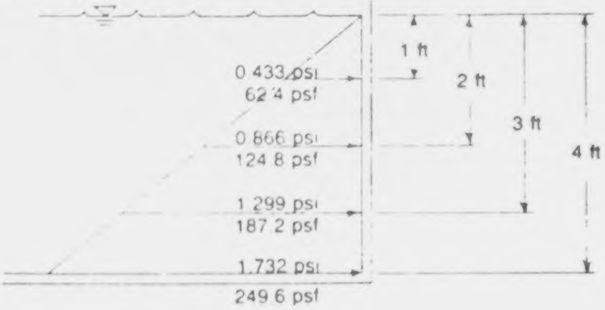
$$\boxed{p,\ \text{psi} = 0.433\ (H,\ \text{ft})}$$

H = feet of head
p = pounds per square *INCH* of pressure

$$\boxed{P,\ \text{lb/sq ft} = 62.4\ (H,\ \text{ft})}$$

H = feet of head
P = pounds per square *FOOT* of pressure

We can now draw a diagram of the pressure acting on the side of a tank. Assume a four-foot deep tank. The pressures shown on the tank are gage pressures. These pressures do not include the atmospheric pressure acting on the surface of the water.



$p_0 = 0.433 \times 0 = 0.0$ psi
$p_1 = 0.433 \times 1 = 0.433$ psi
$p_2 = 0.433 \times 2 = 0.866$ psi
$p_3 = 0.433 \times 3 = 1.299$ psi
$p_4 = 0.433 \times 4 = 1.732$ psi

$P_0 = 62.4 \times 0 = 0.0$ lb/sq ft
$P_1 = 62.4 \times 1 = 62.4$ lb/sq ft
$P_2 = 62.4 \times 2 = 124.8$ lb/sq ft
$P_3 = 62.4 \times 3 = 187.2$ lb/sq ft
$P_4 = 62.4 \times 4 = 249.6$ lb/sq ft

The average *PRESSURE* acting on the tank wall is 1.732 psi/2 = 0.866 psi, or 249.2 psf/2 = 124.8 psf. We divided by two to obtain the average pressure because there is zero pressure at the top and 1.732 psi pressure on the bottom of the wall.

If the wall were five feet long, the pressure would be acting over the entire 20 square foot (5 ft × 4 ft) area of the wall. The total force acting to push the wall would be:

$$\begin{aligned}\text{Force, lb} &= (\text{Pressure, lb/sq ft})(\text{Area, sq ft})\\ &= 124.8 \text{ lb/sq ft} \times 20 \text{ sq ft}\\ &= 2496 \text{ lbs}\end{aligned}$$

If the pressure in psi were used, the problem would be similar:

$$\begin{aligned}\text{Force, lb} &= (\text{Pressure, lb/sq in})(\text{Area, sq in})\\ &= 0.866 \text{ psi} \times 48 \text{ in} \times 60 \text{ in}\\ &= 2494 \text{ lb}^{*}\end{aligned}$$

---

* Difference in answer due to rounding off of decimal points.

The general formula, then, for finding the total force acting on a side wall of a tank is:

$$\boxed{F = 31.2 \times H^2 \times L}$$

F = force in pounds
H = head in feet
L = length of wall in feet
31.2 = constant with units of lbs/cu ft and considers the fact that the force results from H/2 or half the depth of the water which is the average depth. The force is exerted at H/3 from the bottom.

Example: Find the force acting on a five-foot long wall in a four-foot deep tank.

$$\begin{aligned}\text{Force, lb} &= 31.2\ (\text{Head, ft})^2\ (\text{Length, ft})\\ &= 31.2 \text{ lb/cu ft} \times (4 \text{ ft})^2 \times 5 \text{ ft}\\ &= 2496 \text{ lbs}\end{aligned}$$

Occasionally an operator is warned: *NEVER EMPTY A TANK DURING PERIODS OF HIGH GROUNDWATER.* Why? The pressure on the bottom of the tank caused by the water surrounding the tank will tend to float the tank like a cork if the upward force of the water is greater than the weight of the tank.

$$\boxed{F = 62.4 \times H \times A}$$

F = upward force in pounds
H = head of water on tank bottom in feet
A = area of bottom of tank in square feet
62.4 = a constant with units of lbs/cu ft

This formula is approximately true if the tank doesn't crack, leak, or start to float.

Example: Find the upward force on the bottom of an empty tank caused by a groundwater depth of 8 feet above the tank bottom. The tank is 20 ft wide and 40 ft long.

$$\begin{aligned}\text{Force, lb} &= 62.4\ (\text{Head, ft})(\text{Area, sq ft})\\ &= 62.4 \text{ lb/cu ft} \times 8 \text{ ft} \times 20 \text{ ft} \times 40 \text{ ft}\\ &= 399{,}400 \text{ lb}\end{aligned}$$

A.7 VELOCITY AND FLOW RATE

A.70 Velocity

The velocity of a particle or substance is the speed at which it is moving. It is expressed by indicating the length of travel and how long it takes to cover the distance. Velocity can be expressed in almost any distance and time units. For instance, a car may be traveling at a rate of 280 miles per five hours. However, it is normal to express the distance traveled per unit time. The above example would then become:

$$\begin{aligned}\text{Velocity, mi/hr} &= \frac{280 \text{ miles}}{5 \text{ hours}}\\ &= 56 \text{ miles/hour}\end{aligned}$$

The velocity of water in a channel, pipe, or other conduit can be expressed in the same way. If the particle of water travels 600 feet in five minutes, the velocity is:

$$\begin{aligned}\text{Velocity, ft/min} &= \frac{\text{distance, ft}}{\text{time, minutes}}\\ &= \frac{600 \text{ ft}}{5 \text{ min}}\\ &= 120 \text{ ft/min}\end{aligned}$$

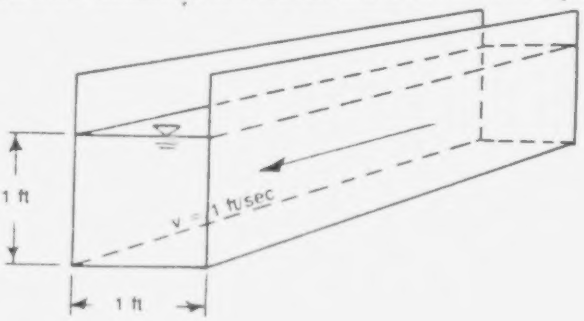
If you wish to express the velocity in feet per second, multiply by 1 min/60 seconds.

NOTE: $\frac{1 \text{ minute}}{60 \text{ seconds}}$ is like $\frac{1}{1}$ and does not change the relative value of the answer. It only changes the form of the answer.

$$\begin{aligned}\text{Velocity, ft/sec} &= (\text{Velocity, ft/min})(1 \text{ min/60 sec})\\ &= \frac{120 \text{ ft}}{\cancel{\text{min}}} \times \frac{1\ \cancel{\text{min}}}{60 \text{ sec}}\\ &= \frac{120 \text{ ft}}{60 \text{ sec}}\\ &= 2 \text{ ft/sec}\end{aligned}$$

A.71 Flow Rate

If water in a one-foot wide channel is one foot deep, then the cross sectional area of the channel is 1 ft × 1 ft = 1 sq ft.



If the velocity in this channel is 1 ft per second, then each second a body of water 1 sq ft in area and 1 ft long will pass a given point. The volume of this body of water would be 1 cubic foot. Since one cubic foot of water would pass by every second, the flow rate would be equal to 1 cubic foot per second, or 1 cfs.

To obtain the flow rate in the above example the velocity was multiplied by the cross sectional area. This is another important general formula.

$\boxed{Q = V \times A}$

Q = flow rate, cfs or cu ft/sec
V = velocity, ft/sec
A = area, sq ft

Example: A rectangular channel 3 feet wide contains water 2 feet deep and flowing at a velocity of 1.5 feet per second. What is the flow rate in cfs?

$$Q = V \times A$$

$$\begin{aligned}\text{Flow rate, cfs} &= \text{Velocity, ft/sec} \times \text{Area, sq ft}\\ &= 1.5\ \text{ft/sec} \times 3\ \text{ft} \times 2\ \text{ft}\\ &= 9\ \text{cu ft/sec}\end{aligned}$$

Example: Flow in a 2.5 foot wide channel is 1.4 ft deep and measures 11.2 cfs. What is the average velocity?

In this problem we want to find the velocity. Therefore, we must rearrange the general formula to solve for velocity.

$$V = \frac{Q}{A}$$

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Flow Rate, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{11.2\ \text{cu ft/sec}}{2.5\ \text{ft} \times 1.4\ \text{ft}}\\ &= \frac{11.2\ \text{ft/sec}}{3.5}\\ &= 3.2\ \text{ft/sec}\end{aligned}$$

Example: Flow in an 8-inch pipe is 500 GPM. What is the average velocity?

$$\begin{aligned}\text{Area, sq ft} &= 0.785\ (\text{Diameter, ft})^2\\ &= 0.785\ (8/12\ \text{ft})^2\\ &= 0.785\ (\tfrac{2}{3}\ \text{ft})^2\\ &= 0.785\ (\tfrac{2}{3}\ \text{ft})(\tfrac{2}{3}\ \text{ft})\\ &= 0.785\ (4/9\ \text{ft}^2)\\ &= 0.35\ \text{sq ft}\end{aligned}$$

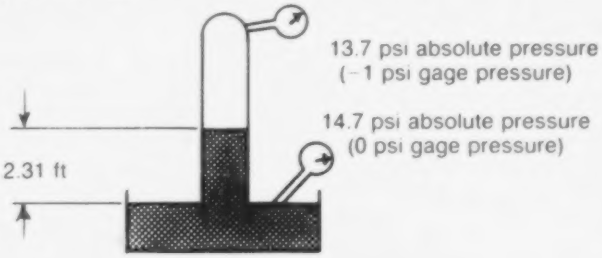
$$\begin{aligned}\text{Flow, cfs} &= \text{Flow, gal/min} \times \frac{\text{cu ft}}{7.48\ \text{gal}} \times \frac{1\ \text{min}}{60\ \text{sec}}\\ &= \frac{500\ \text{gal}}{\text{min}} \times \frac{\text{cu ft}}{7.48\ \text{gal}} \times \frac{1\ \text{min}}{60\ \text{sec}}\\ &= \frac{500\ \text{cu ft}}{448.8\ \text{sec}}\\ &= 1.114\ \text{cfs}\end{aligned}$$

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Flow, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{1.114\ \text{ft}^3\text{/sec}}{0.35\ \text{ft}^2}\\ &= 3.18\ \text{ft/sec}\end{aligned}$$

A.8 PUMPS

A.80 Pressure

Atmospheric pressure at sea level is approximately 14.7 psi. This pressure acts in all directions and on all objects. If a tube is placed upside down in a basin of water and a 1 psi partial vacuum is drawn on the tube, the water in the tube will rise 2.31 feet.



NOTE: 1 ft of water = 0.433 psi; therefore,

$$1\ \text{psi} = \frac{1}{0.433}\ \text{ft} = 2.31\ \text{ft of water}$$

The action of the partial vacuum is what gets water out of a sump or well and up to a pump. It is not sucked up, but it is pushed up by atmospheric pressure on the water surface in the sump. If a complete vacuum could be drawn, the water would rise 2.31 × 14.7 = 33.9 feet; but this is impossible to achieve. The practical limit of the suction lift of a positive displacement pump is about 22 feet, and that of a centrifugal pump is 15 feet.

A.81 Work

Work can be expressed as lifting a weight a certain vertical distance. It is usually defined in terms of foot-pounds.

Example: A 165-pound man runs up a flight of stairs 20 feet high. How much work did he do?

$$\begin{aligned}\text{Work, ft-lb} &= \text{Weight, lb} \times \text{Height, ft}\\ &= 165\ \text{lb} \times 20\ \text{ft}\\ &= 3300\ \text{ft-lb}\end{aligned}$$

A.82 Power

Power is a rate of doing work and is usually expressed in foot-pounds per minute.

Example: If the man in the above example runs up the stairs in three seconds, how much power has he exerted?

$$\begin{aligned}\text{Power, ft-lbs/sec} &= \frac{\text{Work, ft-lb}}{\text{Time, sec}}\\ &= \frac{3300\ \text{ft-lbs}}{3\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{\text{minute}}\\ &= 66{,}000\ \text{ft-lb/min}\end{aligned}$$

A.83 Horsepower

Horsepower is also a unit of power. One horsepower is defined as 33,000 ft-lbs per minute or 746 watts.

Example: How much horsepower has the man in the previous example exerted as he climbs the stairs?

$$\text{Horsepower, HP} = (\text{Power, ft-lb/min})\left(\frac{\text{HP}}{33{,}000 \text{ ft-lb/min}}\right)$$

$$= 66{,}000 \text{ ft-lb/min} \times \frac{\text{Horsepower}}{33{,}000 \text{ ft-lb/min}}$$

$$= 2 \text{ HP}$$

Work is also done by lifting water. If the flow from a pump is converted to a weight of water and multiplied by the vertical distance it is lifted, the amount of work or power can be obtained.

$$\text{Horsepower, HP} = \frac{\text{Flow, gal}}{\text{min}} \times \text{Lift, ft} \times \frac{8.34 \text{ lb}}{\text{gal}} \times \frac{\text{Horsepower}}{33{,}000 \text{ ft-lb/min}}$$

Solving the above relation, the amount of horsepower necessary to lift the water is obtained. This is called water horsepower.

$$\text{Water, HP} = \frac{(\text{Flow, GPM})(\text{H, ft})}{3960^*}$$

However, since pumps are not 100% efficient (they cannot transmit all the power put into them), the horsepower supplied to a pump is greater than the water horsepower. Horsepower supplied to the pump is called brake horsepower.

$$\boxed{\text{Brake, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}}$$

E_p = Efficiency of Pump (Usual range 50-85%, depending on type and size of pump)

Motors are also not 100% efficient; therefore, the power supplied to the motor is greater than the motor transmits.

$$\boxed{\text{Motor, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}}$$

E_m = Efficiency of motor (Usual range 80-95%, depending on type and size of motor)

The above formulas have been developed for the pumping of water and wastewater which have a specific gravity of 1.0. If other liquids are to be pumped, the formulas must be multiplied by the specific gravity of the liquid.

Example: A flow of 500 GPM of water is to be pumped against a total head of 100 feet by a pump with an efficiency of 70%. What is the pump horsepower?

$$\text{Brake, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}$$

$$= \frac{500 \times 100}{3960 \times 0.70}$$

$$= 18 \text{ HP}$$

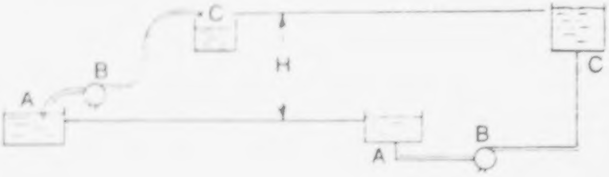
Example: Find the horsepower required to pump gasoline (specific gravity = 0.75) in the above problem.

$$\text{Brake, HP} = \frac{500 \times 100 \times 0.75}{3960 \times 0.70}$$

$$= 13.5 \text{ HP}$$ (gasoline is lighter and requires less horsepower)

A.84 Head

Basically, the head that a pump must work against is determined by measuring the vertical distance between the two water surfaces, or the distance the water must be lifted. This is called the static head. Two typical conditions for lifting water are shown below.



If a pump were designed in the above examples to pump only against head H, the water would never reach the intended point. The reason for this is that the water encounters friction in the pipelines. Friction depends on the roughness and length of pipe, the pipe diameter, and the flow velocity. The turbulence caused at the pipe entrance (point A); the pump (point B); the pipe exit (point C); and at each elbow, bend, or transition also adds to these friction losses. Tables and charts are available in Section A.88 for calculation of these friction losses so they may be added to the measured or static head to obtain the total head. For short runs of pipe which do not have high velocities, the friction losses are generally less than 10 percent of the static head.

Example: A pump is to be located eight feet above a wet well and must lift 1.8 MGD another 50 feet to a storage reservoir. If the pump has an efficiency of 75% and the motor an efficiency of 90%, what is the cost of the power consumed if one kilowatt hour costs 4 cents?

Since we are not given the length or size of pipe and the number of elbows or bends, we will assume friction to be 10% of static head.

$$\text{Static Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$

$$= 8 \text{ ft} + 50 \text{ ft}$$

$$= 58 \text{ ft}$$

$$\text{Friction Losses, ft} = 0.1 \text{ (Static Head, ft)}$$

$$= 0.1 \text{ (58 ft)}$$

$$= 5.8 \text{ ft}$$

$$\text{Total Dynamic Head, ft} = \text{Static Head, ft} + \text{Friction Losses, ft}$$

$$= 58 \text{ ft} + 5.8 \text{ ft}$$

$$= 63.8 \text{ ft}$$

$$\text{Flow, GPM} = \frac{1{,}800{,}000 \text{ gal}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{24\ \cancel{\text{hr}}} \times \frac{1\ \cancel{\text{hr}}}{60 \text{ min}}$$

$$= 1250 \text{ GPM}$$ (assuming pump runs 24 hours per day)

$$^* \frac{8.34 \text{ lb}}{\text{gal}} \times \frac{\text{HP}}{33{,}000 \text{ ft-lb/min}} = \frac{1}{3960}$$

1 gallon weighs 8.34 pounds and 1 horsepower is the same as 33,000 ft-lb/min.

H or Head in feet is the same as Lift in feet.

$$\text{Motor, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}$$

$$= \frac{1250 \times 63.8}{3960 \times 0.75 \times 0.9}$$

$$= 30 \text{ HP}$$

$$\text{Kilowatt-hrs} = 30\ \cancel{\text{HP}} \times 24 \text{ hrs/day} \times 0.746 \text{ kw/}\cancel{\text{HP}}^{*}$$

$$= 537 \text{ kilowatt-hrs/day}$$

$$\text{Cost} = \text{KWH} \times \$0.04/\text{KWH}$$

$$= 537 \times 0.04$$

$$= \$21.48/\text{day}$$

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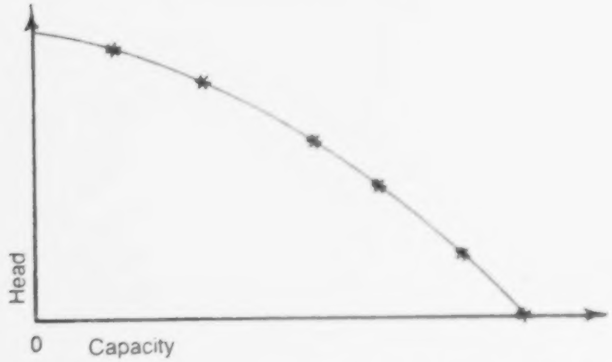
* See Conversion Tables — Section A.10. "Power."

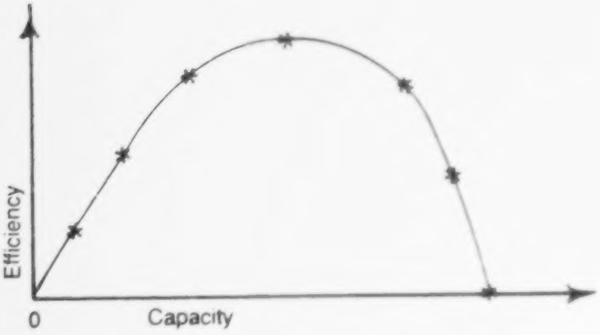
A.85 Pump Characteristics

The discharge of a centrifugal pump, unlike a positive displacement pump, can be made to vary from zero to a maximum capacity which depends on the speed, head, power, and specific impeller design. The interrelation of capacity, efficiency, head, and power is known as the characteristics of the pump.

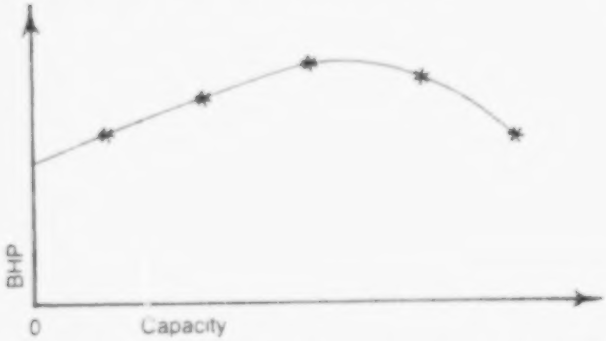
The first relation normally looked at when searching for a pump is the head vs. capacity. The head of a centrifugal pump normally rises as the capacity is reduced. If the values are plotted on a graph they appear as follows:



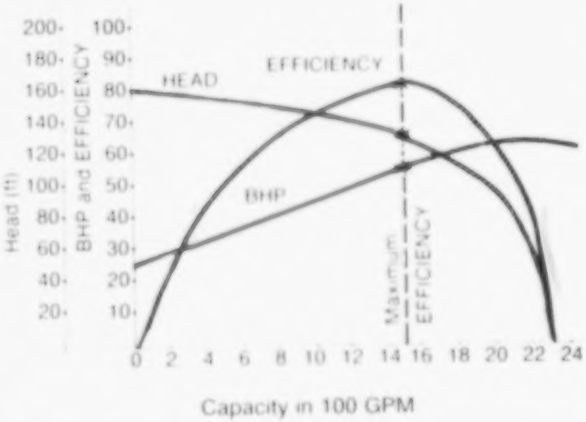
Another important characteristic is the pump efficiency. It begins from zero at no discharge, increases to a maximum, and then drops as the capacity is increased. Following is a graph of efficiency vs. capacity:



The last important characteristic is the brake horsepower or the power input to the pump. The brake horsepower usually increases with increasing capacity until it reaches a maximum, then it normally reduces slightly.



These pump characteristic curves are quite important. Pump sizes are normally picked from these curves rather than calculations. For ease of reading, the three characteristic curves are normally plotted together. A typical graph of pump characteristics is shown as follows:



The curves show that the maximum efficiency for the particular pump in question occurs at approximately 1475 GPM, a head of 132 feet, and a brake horsepower of 58. Operating at this point the pump has an efficiency of approximately 85%. This can be verified by calculation:

$$\text{BHP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E}$$

As previously explained, a number can be written over one without changing its value:

$$\frac{\text{BHP}}{1} = \frac{\text{GPM} \times \text{H}}{3960 \times E}$$

Since the formula is now in ratio form, it can be cross multiplied.

$$\text{BHP} \times 3960 \times E = \text{GPM} \times \text{H} \times 1$$

Solving for E,

$$E = \frac{\text{GPM} \times \text{H}}{3960 \times \text{BHP}}$$

$$E = \frac{1475 \text{ GPM} \times 132 \text{ ft}}{3960 \times 58 \text{ HP}}$$

$$= 0.85 \text{ or } 85\% \text{ (Check)}$$

The preceding is only a brief description of pumps to familiarize the operator with their characteristics. The operator does not normally specify the type and size of pump needed at a plant. If a pump is needed, the operator should be able to supply the information necessary for a pump supplier to provide the best possible pump for the lowest cost. Some of the information needed includes:

1. Flow range desired
2. Head conditions
   a. Suction head or lift
   b. Pipe and fitting friction head
   c. Discharge head
3. Type of fluid pumped and temperature
4. Pump location

A.86 Evaluation of Pump Performance

1. Capacity

Sometimes it is necessary to determine the capacity of a pump. This can be accomplished by determining the time it takes a pump to fill or empty a portion of a wet well or diversion box when all inflow is blocked off.

EXAMPLE:

a. Measure the size of the wet well.

Length = 10 ft
Width = 10 ft
Depth = 5 ft (We will measure the time it takes to lower the well a distance of five feet)

$$\text{Volume, cu ft} = \text{L, ft} \times \text{W, ft} \times \text{D, ft}$$
$$= 10\text{ ft} \times 10\text{ ft} \times 5\text{ ft}$$
$$= 500\text{ cu ft}$$

b. Record time for water to drop five feet in wet well.

Time = 10 minutes 30 seconds
= 10.5 minutes

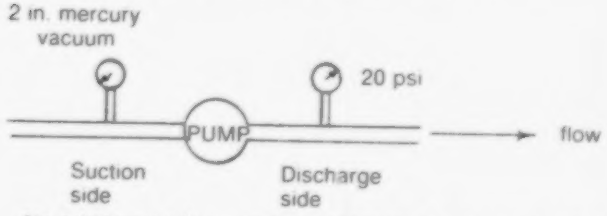
c. Calculate pumping rate or capacity.

$$\text{Pumping Rate, GPM} = \frac{\text{Volume, gallons}}{\text{Time, minutes}}$$
$$= \frac{(500\text{ cu ft})(7.5\text{ gal/cu ft})}{10.5\text{ min}}$$
$$= \frac{3750}{10.5}$$
$$= 357\text{ GPM}$$

If you know the total dynamic head and have the pump's performance curves, you can determine if the pump is delivering at design capacity. If not, try to determine the cause (see Chapter 18, "Maintenance"). After a pump overhaul, the pump's actual performance (flow, head, power and efficiency) should be compared with the pump manufacturer's performance curves. This procedure for calculating the rate of filling or emptying of a wet well or diversion box can be used to calibrate flow meters.

2. Efficiency

To estimate the efficiency of the pump in the previous example, the total head must be known. This head may be estimated by measuring the suction and discharge pressure. Assume these were measured as follows:



No additional information is necessary if we assume the pressure gages are at the same height and the pipe diameters are the same. Both pressure readings must be converted to feet.

$$\text{Suction Lift, ft} = 2\text{ in Mercury} \times \frac{1.133\text{ ft water}^*}{1\text{ in Mercury}}$$
$$= 2.27\text{ ft}$$
$$\text{Discharge Head, ft} = 20\text{ psi} \times 2.31\text{ ft/psi}^*$$
$$= 46.20\text{ ft}$$
$$\text{Total Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$
$$= 2.27\text{ ft} + 46.20\text{ ft}$$
$$= 48.47\text{ ft}$$

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*See Conversion Tables — Section A.10, "Pressure."

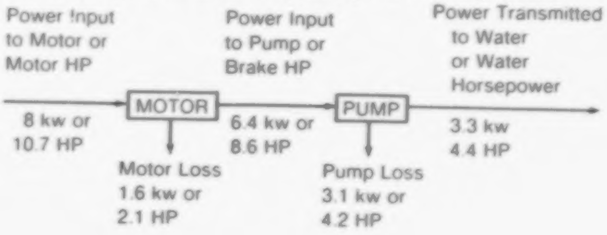
Calculate the power output of the pump or water horsepower:

$$\text{Water Horsepower, HP} = \frac{(\text{Flow GPM})(\text{Head, ft})}{3960}$$
$$= \frac{(357\text{ GPM})(48.47\text{ ft})}{3960}$$
$$= 4.4\text{ HP}$$

To estimate the efficiency of the pump, measure the kilowatts drawn by the pump motor. Assume the meter indicates 8000 watts or 8 kilowatts. The manufacturer claims the electric motor is 80% efficient.

$$\text{Brake Horsepower, HP} = (\text{Power to elec. motor})(\text{motor eff.})$$
$$= \frac{(8\text{ kw})(0.80)}{0.746\text{ kw/HP}}$$
$$= 8.6\text{ HP}$$
$$\text{Pump Efficiency, \%} = \frac{\text{Water Horsepower, HP} \times 100\%}{\text{Brake Horsepower, HP}}$$
$$= \frac{4.4\text{ HP} \times 100\%}{8.6\text{ HP}}$$
$$= 51\%$$

The following diagram may clarify the above problem:


Power Input to Motor or Motor HP
Power Input to Pump or Brake HP
Power Transmitted to Water or Water Horsepower
MOTOR
PUMP
8 kw or 10.7 HP
6.4 kw or 8.6 HP
3.3 kw 4.4 HP
Motor Loss 1.6 kw or 2.1 HP
Pump Loss 3.1 kw or 4.2 HP

The wire-to-water efficiency is the efficiency of the power input to produce water horsepower.

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, HP}}{\text{Power Input, HP}} \times 100\%$$

$$= \frac{4.4 \text{ HP}}{10.7 \text{ HP}} \times 100\%$$

$$= 41\%$$

A.87 Pump Speed — Performance Relationships

Changing the velocity of a centrifugal pump will change its operating characteristics. If the speed of a pump is changed, the flow, head developed, and power requirements will change. The operating characteristics of the pump will change with speed approximately as follows:

$$\text{Flow, } Q_n = \left[\frac{N_n}{N_r}\right] Q_r$$

$$\text{Head, } H_n = \left[\frac{N_n}{N_r}\right]^2 H_r$$

$$\text{Power, } P_n = \left[\frac{N_n}{N_p}\right]^3 P_r$$

r = rated

n = now

N = pump speed

Actually, pump efficiency does vary with speed; therefore, these formulas are not quite correct. If speeds do not vary by more than a factor of two (if the speeds are not doubled or cut in half), the results are close enough. Other factors contributing to changes in pump characteristic curves include impeller wear and roughness in pipes.

Example: To illustrate these relationships, assume a pump has a rated capacity of 600 GPM, develops 100 ft of head, and has a power requirement of 15 HP when operating at 1500 rpm. If the efficiency remains constant, what will be the operating characteristics if the speed drops to 1200 rpm?

Calculate new flow rate or capacity:

$$\text{Flow, } Q_n = \left[\frac{N_n}{N_r}\right] Q_r$$

$$= \left[\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right] 600 \text{ GPM}$$

$$= \left[\frac{4}{5}\right] 600 \text{ GPM}$$

$$= (4)(120 \text{ GPM})$$

$$= 480 \text{ GPM}$$

Calculate new head:

$$\text{Head, } H_n = \left[\frac{N_n}{N_r}\right]^2 H_r$$

$$= \left[\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right]^2 100 \text{ ft}$$

$$= \left(\frac{4}{5}\right)^2 100 \text{ ft}$$

$$= \left(\frac{16}{25}\right)(100 \text{ ft})$$

$$= 16 \ (4 \text{ ft})$$

$$= 64 \text{ ft}$$

Calculate new power requirement:

$$\text{Power, } P_n = \left[\frac{N_n}{N_r}\right]^3 P_r$$

$$= \left(\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right)^3 15 \text{ HP}$$

$$= \left(\frac{4}{5}\right)^3 15 \text{ HP}$$

$$= \left(\frac{64}{125}\right) 15 \text{ HP}$$

$$= \left(\frac{64}{25}\right)(3 \text{ HP})$$

$$= 7.7 \text{ HP}$$

A.88 Friction or Energy Losses

Whenever water flows through pipes, valves and fittings, energy is lost due to pipe friction (resistance), friction in valves and fittings, and the turbulence resulting from the flowing water changing its direction. Figure A.1 can be used to convert the friction losses through valves and fittings to lengths of straight pipe that would produce the same amount of friction losses. To estimate the friction or energy losses resulting from water flowing in a pipe system, we need to know:

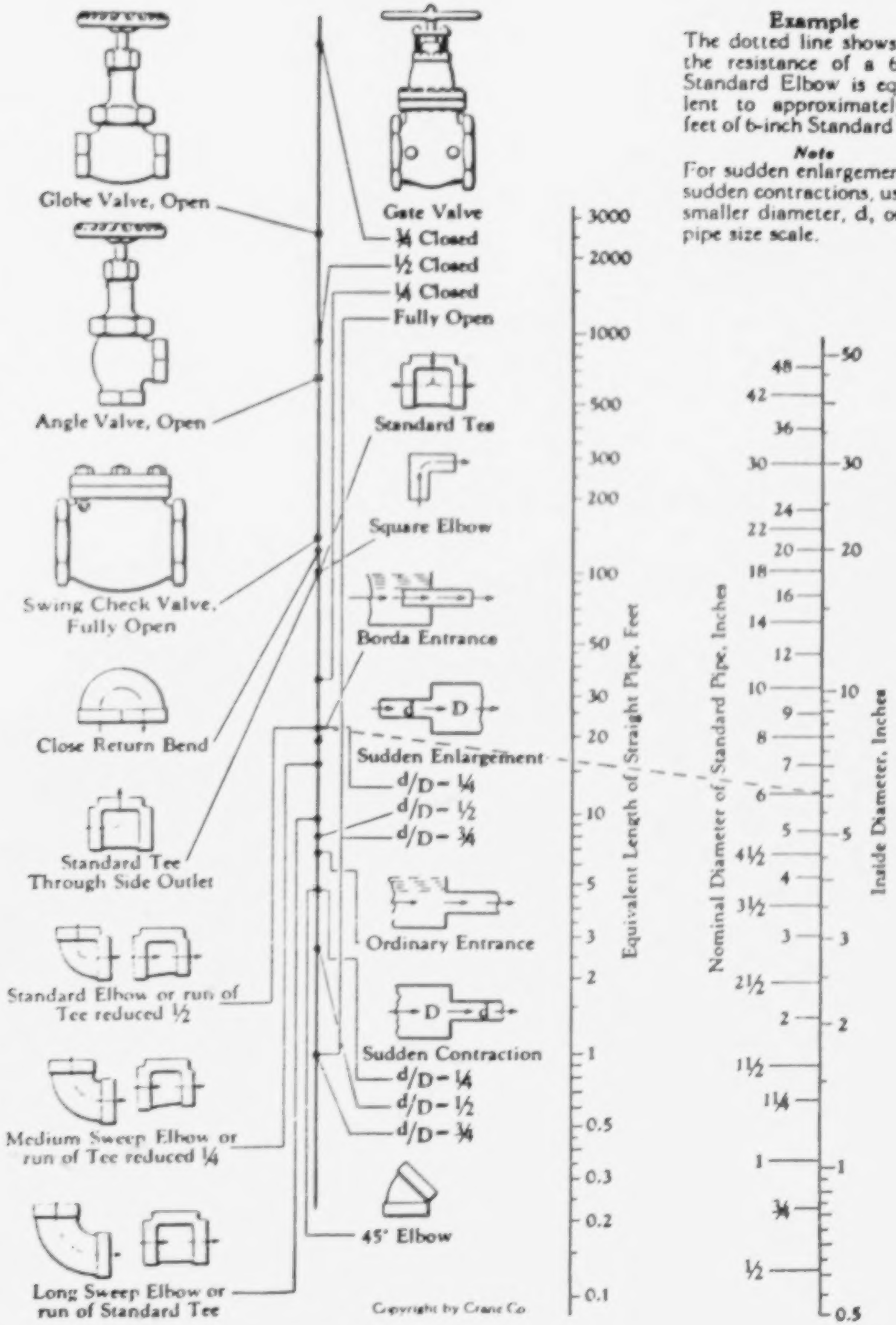
1. Water flow rate,
2. Pipe size or diameter and length, and
3. Number, size and type of valve fittings.

An easy way to estimate friction or energy losses is to follow the following steps:

1. Determine the flow rate;
2. Determine the diameter and length of pipe;
3. Convert all valves and fittings to equivalent lengths of straight pipe (see Figure A.1);
4. Add up total length of equivalent straight pipe; and
5. Estimate friction or energy losses by using Figure A.2. With the flow in GPM and diameter of pipe, find the friction loss per 100 feet of pipe. Multiply this value by equivalent length of straight pipe.

The procedure for using Figure A.1 is very easy. Locate the type of valve or fitting you wish to convert to an equivalent pipe length; find its diameter on the right-hand scale; and draw a straight line between these two points to locate the equivalent length of straight pipe.

Example: Estimate the friction losses in the piping system of a pump station when the flow is 1,000 GPM. The 8-inch suction line is 10 feet long and contains a 90-degree bend (long sweep elbow), a gate valve and an 8-inch by 6-inch reducer at the inlet to the pump. The 6-inch discharge line is 30 feet long and contains a check valve, a gate valve, and three 90-degree bends (medium sweep elbows):


Globe Valve, Open
Angle Valve, Open
Swing Check Valve, Fully Open
Close Return Bend
Standard Tee Through Side Outlet
Standard Elbow or run of Tee reduced ½
Medium Sweep Elbow or run of Tee reduced ¼
Long Sweep Elbow or run of Standard Tee
Gate Valve
¾ Closed
½ Closed
¼ Closed
Fully Open
Standard Tee
Square Elbow
Borda Entrance
d
D
Sudden Enlargement
d/D = ¼
d/D = ½
d/D = ¾
Ordinary Entrance
D
d
Sudden Contraction
d/D = ¼
d/D = ½
d/D = ¾
45° Elbow
Copyright by Crane Co.
3000
2000
1000
500
300
200
100
50
30
20
10
5
3
2
1
0.5
0.3
0.2
0.1
Equivalent Length of Straight Pipe, Feet
48
42
36
30
24
22
20
18
16
14
12
10
9
8
7
6
5
4½
4
3½
3
2½
2
1½
1¼
1
¾
½
Nominal Diameter of Standard Pipe, Inches
50
30
20
10
5
3
2
1
0.5
Inside Diameter, Inches

Example

The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note

For sudden enlargements or sudden contractions, use the smaller diameter, d, on the pipe size scale.

Fig. A.1 Resistance of valves and fittings to flow of water

(Reprinted by permission of Crane Co.)

U.S. GPM	0.5 in.		0.75 in.		1 in.		1.25 in.		1.5 in.		2 in.		2.5 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
10	10.56	95.9	6.02	23.0	3.71	6.86	2.15	1.77	1.58	.83	.96	.25	.67	.11
20			12.0	86.1	7.42	25.1	4.29	6.34	3.15	2.94	1.91	.87	1.34	.36
30					11.1	54.6	6.44	13.6	4.73	6.26	2.87	1.82	2.01	.75
40					14.8	95.	8.58	23.5	6.30	10.79	3.82	3.10	2.68	1.28
50							10.7	36.0	7.88	16.4	4.78	4.67	3.35	1.94
60							12.9	51.0	9.46	23.2	5.74	6.59	4.02	2.72
70							15.0	68.8	11.03	31.3	6.69	8.86	4.69	3.63
80							17.2	89.2	12.6	40.5	7.65	11.4	5.36	4.66
90									14.2	51.0	8.60	14.2	6.03	5.82
100									15.8	62.2	9.56	17.4	6.70	7.11
120									18.9	88.3	11.5	24.7	8.04	10.0
140											13.4	33.2	9.38	13.5
160											15.3	43.0	10.7	17.4
180											17.2	54.1	12.1	21.9
200											19.1	66.3	13.4	26.7
220											21.0	80.0	14.7	32.2
240											22.9	95.0	16.1	38.1
260													17.4	44.5
280													18.8	51.3
300													20.1	58.5
350													23.5	79.2

U.S. GPM	3 in.		4 in.		5 in.		6 in.		8 in.		10 in.		12 in.		14 in.		16 in.		18 in.		20 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
20	.91	.15																				
40	1.82	.55	1.02	.13																		
50	2.72	1.17	1.53	.28	.96	.08																
80	3.63	2.02	2.04	.48	1.28	.14	.91	.06														
100	4.54	3.10	2.55	.73	1.60	.20	1.13	.10														
120	5.45	4.40	3.06	1.03	1.92	.29	1.36	.13														
140	6.35	5.93	3.57	1.38	2.25	.38	1.59	.18														
160	7.26	7.71	4.08	1.78	2.57	.49	1.82	.23														
180	8.17	9.73	4.60	2.24	2.89	.61	2.04	.28														
200	9.08	11.9	5.11	2.74	3.21	.74	2.27	.35														
220	9.98	14.3	5.62	3.28	3.53	.88	2.50	.42	1.40	.10												
240	10.9	17.0	6.13	3.88	3.85	1.04	2.72	.49	1.53	.12												
260	11.8	19.8	6.64	4.54	4.17	1.20	2.95	.57	1.66	.14												
280	12.7	22.8	7.15	5.25	4.49	1.38	3.18	.66	1.79	.16												
300	13.6	26.1	7.66	6.03	4.81	1.58	3.40	.75	1.91	.18												
350			8.94	8.22	5.61	2.11	3.97	1.01	2.24	.24												
400			10.20	10.7	6.41	2.72	4.54	1.30	2.55	.30												
460			11.45	13.4	7.22	3.41	5.11	1.64	2.87	.38	1.84	.12										
500			12.8	16.6	8.02	4.16	5.67	2.02	3.19	.46	2.04	.15	1.42	.06								
550			14.0	19.9	8.82	4.98	6.24	2.42	3.51	.56	2.25	.18	1.56	.07								
600					9.62	5.88	6.81	2.84	3.83	.66	2.45	.21	1.70	.08	1.25	.04						
700					11.2	7.93	7.94	3.87	4.47	.88	2.86	.29	1.99	.12	1.46	.05						
800					12.8	10.22	9.08	5.06	5.11	1.14	3.27	.37	2.27	.15	1.67	.07						
900					14.4	12.9	10.2	6.34	5.74	1.44	3.68	.46	2.55	.18	1.88	.09						
1000							11.3	7.73	6.38	1.76	4.09	.57	2.84	.22	2.08	.11						
1100							12.5	9.80	7.02	2.14	4.49	.68	3.12	.27	2.29	.13						
1200							13.6	11.2	7.66	2.53	4.90	.81	3.40	.32	2.50	.15	1.91	.08				
1300							14.7	13.0	8.30	2.94	6.31	.95	3.69	.37	2.71	.17	2.07	.09				
1400									8.93	3.40	5.72	1.09	3.97	.43	2.92	.20	2.23	.10				
1500									9.57	3.91	6.13	1.25	4.26	.49	3.13	.23	2.34	.12				
1600									10.2	4.45	6.54	1.42	4.54	.55	3.33	.25	2.55	.13	2.02	.07		
1700									10.8	5.00	6.94	1.60	4.87	.62	3.54	.29	2.71	.15	2.15	.08		
1800									11.5	5.58	7.35	1.78	5.11	.70	3.75	.32	2.87	.16	2.27	.09		
1900									12.1	6.19	7.76	1.97	5.39	.77	3.96	.35	3.03	.18	2.40	.10		
2000									12.8	6.84	8.17	2.17	5.67	.86	4.17	.39	3.19	.20	2.52	.11		
2500											10.2	3.38	7.10	1.33	5.21	.60	3.99	.31	3.15	.17		
3000											12.3	4.79	8.51	1.88	6.25	.86	4.79	.44	3.78	.24	3.06	.14
3500											14.3	6.55	9.93	2.56	7.29	1.16	5.58	.58	4.41	.32	3.57	.19
4000													11.3	3.31	8.34	1.50	6.38	.75	5.04	.42	4.08	.24
4500													12.8	4.18	9.38	1.88	7.18	.95	5.67	.53	4.59	.31
5000													14.7	5.13	10.4	2.30	7.98	1.17	6.30	.65	5.11	.38
6000															12.5	3.31	9.57	1.66	7.56	.92	6.13	.53
7000															14.6	4.50	11.2	2.26	8.83	1.24	7.15	.72
8000																	12.8	2.96	10.09	1.61	8.17	.94
9000																	14.4	3.73	11.3	2.02	9.19	1.18
10000																			12.6	2.48	10.2	1.45

No allowance has been made for age, differences in diameter, or any other abnormal condition of interior surface. Any Factor of Safety must be estimated from the local conditions and the requirements of each particular installation. For general purposes, 15% is a responsible Factor of Safety.

Fig. A.2 Friction Loss for Water in Feet Per 100 Feet of Pipe

(Reprinted from the 10th Edition of the Standards of the Hydraulic Institute, 122 East 42nd Street, New York)

SUCTION LINE (8-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	10
2. 90-degree bend	14
3. Gate valve	4
4. 8-inch by 6-inch reducer	17
5. Ordinary entrance	12
Total equivalent length	57 feet

Friction loss (Fig. A.2) = 1.76 ft/100 ft of pipe

DISCHARGE LINE (6-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	30
2. Check valve	38
3. Gate valve	4
4. Three 90-degree bends (3) (14)	42
Total equivalent length	114 feet

Friction loss (Fig. A.2) = 7.73 ft/100 ft of pipe

Estimate the total friction losses in pumping system for a flow of 1,000 GPM.

SUCTION

Loss = (1.76 ft/100 ft) (57 ft) = 1.0 Ft

DISCHARGE

Loss = (7.73 ft/100 ft) (114 ft) = 8.8 ft

Total friction losses, ft = 9.8 ft

A.9 STEPS IN SOLVING PROBLEMS

A.90 Identification of Problem

To solve any problem, you have to identify the problem, determine what kind of answer is needed, and collect the information needed to solve the problem. A good approach to this type of problem is to examine the problem and make a list of *KNOWN* and *UNKNOWN* information.

Example: Find the theoretical detention time in a rectangular sedimentation tank 8 feet deep, 30 feet wide, and 60 feet long when the flow is 1.4 MGD.

	Known	Unknown
Depth	= 8 ft	Detention Time, hours
Width	= 30 ft	
Length	= 60 ft	
Flow	= 1.4 MGD	

Sometimes a drawing or sketch will help to illustrate a problem and indicate the knowns, unknowns, and possibly additional information needed.

A.91 Selection of Formula

Most problems involving mathematics in water treatment plant operation can be solved by selecting the proper formula, inserting the known information, and calculating the unknown. In our example, we could look in Chapter 4, "Sedimentation," or in Section A.11 of this chapter, "Basic Formulas," to find a formula for calculating detention time. From Section A.11:

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

To convert the known information to fit the terms in a formula sometimes requires extra calculations. The next step is to find the values of any terms in the formula that are not in the list of known values.

$$\begin{aligned}\text{Flow, gal/day} &= 1.4\text{ MGD}\\ &= 1{,}400{,}000\text{ gal/day}\end{aligned}$$

From Section A.30:

$$\begin{aligned}\text{Tank Volume, cu ft} &= (\text{Length, ft})(\text{Width, ft})(\text{Height, ft})\\ &= 60\text{ ft} \times 30\text{ ft} \times 8\text{ ft}\\ &= 14{,}400\text{ cu ft}\end{aligned}$$

Solution of Problem:

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}\\ &= \frac{(14{,}400\text{ cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{1{,}400{,}000\text{ gal/day}}\\ &= 1.85\text{ hr}\end{aligned}$$

The remainder of this section discusses the details that must be considered in solving this problem.

A.92 Arrangement of Formula

Once the proper formula is selected, you may have to rearrange the terms to solve for the unknown term. From Section A.71, "Flow Rate," we can develop the formula:

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Cross-Sectional Area, sq ft}}$$

$$\text{or} \qquad V = \frac{Q}{A}$$

In this equation if Q and A were given, the equation could be solved for V. If V and A were known, the equation would have to be rearranged to solve for Q. To move terms from one side of an equation to another, use the following rule:

When moving a term or number from one side of an equation to the other, move the numerator (top) of one side to denominator (bottom) of the other; or from the denominator (bottom) of one side to the numerator (top) of the other.

$$V = \frac{Q}{A} \text{ or } Q = AV \text{ or } A = \frac{Q}{V}$$

If the volume of a sedimentation tank and the desired detention time were given, the detention time formula could be rearranged to calculate the design flow.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

By rearranging the terms

$$\text{Flow, gal/day} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

A.93 Unit Conversions

Each term in a formula or mathematical calculation must be of the correct units. The area of a rectangular clarifier (Area, sq ft = Length, ft × Width, ft) can't be calculated in square feet if the width is given as 246 inches or 20 feet 6 inches. The width must be converted to 20.5 feet. In the example problem, if the tank volume were given in gallons, then the 7.48 gal/cu ft would not be needed. THE UNITS IN A FORMULA MUST ALWAYS BE CHECKED BEFORE ANY CALCULATIONS ARE PERFORMED TO AVOID TIME-CONSUMING MISTAKES.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

$$= \frac{\cancel{\text{cu ft}}}{} \times \frac{\cancel{\text{gal}}}{\cancel{\text{cu ft}}} \times \frac{\text{hr}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{\cancel{\text{gal}}}$$

= hr (all other units cancel)

NOTE: We have hours = hr. One should note that the hour unit on both sides of the equation can be cancelled out and nothing would remain. This is one more check that we have the correct units. By rearranging the detention time formula, other unknowns could be determined.

If the design detention time and design flow were known, the required capacity of the tank could be calculated.

$$\text{Tank Volume, cu ft} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}$$

If the tank volume and design detention time were known, the design flow could be calculated.

$$\text{Flow, gal/day} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Detention Time, hrs}}$$

Rearrangement of the detention time formula to find other unknowns illustrates the need to always use the correct units.

A.94 Calculations

Sections A.12, "Multiplication," and A.13, "Division," outline the steps to follow in mathematical calculations. In general, do the calculations inside parentheses ( ) first and brackets [ ] next. Calculations should be done above and below the divison line before dividing.

$$\text{Detention Time, hrs} = \frac{[(\text{Tank, Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})]}{\text{Flow, gal/day}}$$

$$= \frac{[(14{,}400\ \text{cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})]}{1{,}400{,}000\ \text{gal/day}}$$

$$= \frac{2{,}585{,}088\ \text{gal-hr/day}}{1{,}400{,}000\ \text{gal/day}}$$

$$= 1.85,\ \text{or}$$

$$= 1.9\ \text{hr}$$

A.95 Significant Figures

In calculating the detention time in the previous section, the answer is given as 1.9 hr. The answer could have been calculated:

$$\text{Detention Time, hrs} = \frac{2{,}585{,}088\ \text{gal-hr/day}}{1{,}400{,}000\ \text{gal/day}}$$

$$= 1.846491429\ \ldots\ \text{hours}$$

How does one know when to stop dividing? Common sense and significant figures both help.

First, consider the meaning of detention time and the measurements that were taken to determine the knowns in the formula. Detention time in a tank is a theoretical value and assumes that all particles of water throughout the tank move through the tank at the same velocity. This assumption is not correct; therefore, detention time can only be a representative time for some of the water particles.

Will the flow of 1.4 MGD be constant throughout the 1.9 hours, and is the flow exactly 1.4 MGD, or could it be 1.35 MGD or 1.428 MGD? A carefully calibrated flow meter may give a reading within 2% of the actual flow rate. Flows into a tank fluctuate and flow meters do not measure flows extremely accurately; so the detention time again appears to be a representative or typical detention time.

Tank dimensions are probably satisfactory within 0.1 ft. A flow meter reading of 1.4 MGD is less precise and it could be 1.3 or 1.5 MGD. A 0.1 MGD flow meter error when the flow is 1.4 MGD is (0.1/1.4) × 100% = 7% error. A detention time of 1.9 hours, based on a flow meter reading error of plus or minus 7%, also could have the same error or more, even if the flow was constant. Therefore, the detention time error could be 1.9 hours × 0.07 = ±0.13 hours.

In most of the calculations in the operation of water treatment plants, the operator uses measurements determined in the lab or read from charts, scales, or meters. The accuracy of every measurement depends on the sample being measured, the equipment doing the measuring, and the operator reading or measuring the results. Your estimate is no better than the least precise measurement. Do not retain more than one doubtful number.

To determine how many figures or numbers mean anything in an answer, the approach called "significant figures" is used. In the example the flow was given in two significant figures (1.4 MGD), and the tank dimensions could be considered accurate to the nearest tenth of a foot (depth = 9.0 ft) or two significant figures. Since all measurements and the constants contained two significant figures, the results should be reported as two significant figures or 1.9 hours. The calculations are normally carried out to three significant figures (1.85 hours) and rounded off to two significant figures (1.9 hours).

Decimal points require special attention when determining the number of significant figures in a measurement.

Measurement	Significant Figures
0.00325	3
11.078	5
21,000.	2

Example: The distance between two points was divided into three sections, and each section was measured by a different group. What is the distance between the two points if each group reported the distance if measured as follows:

Group	Distance, ft	Significant Figures
A	11,300.	3
B	2,438.9	5
C	87.62	4
Total Distance	13,826.52	

Group A reported the length of the section it measured to three significant figures; therefore, the distance between the two points should be reported as 13,800 feet (3 significant figures).

When adding, substracting, multiplying, or dividing, the number of significant figures in the answer should not be more than the term in the calculations with the least number of significant figures.

A.96 Check Your Results

After having completed your calculations, you should carefully examine your calculations and answer. Does the answer seem reasonable? If possible, have another operator check your calculations before making any operational changes.

A.10 BASIC CONVERSION FACTORS (ENGLISH SYSTEM)

UNITS		
1,000,000	= 1 Million	1,000,000/1 Million
LENGTH		
12 in	= 1 ft	12 in/ft
3 ft	= 1 yd	3 ft/yd
5280 ft	= 1 mi	5280 ft/mi
AREA		
144 sq in	= 1 sq ft	144 sq in/sq ft
43,560 sq ft	= 1 acre	43,560 sq ft/ac
VOLUME		
7.48 gal	= 1 cu ft	7.48 gal/cu ft
1000 m*L*	= 1 liter	1000 m*L*/*L*
3.785 *L*	= 1 gal	3.785 *L*/gal
231 cu in	= 1 gal	231 cu in/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
454 gm	= 1 lb	454 gm/lb
2.2 lbs	= 1 kg	2.2 lbs/kg
POWER		
0.746 kw	= 1 HP	0.746 kw/HP
DENSITY		
8.34 lbs	= 1 gal	8.34 lbs/gal
62.4 lbs	= 1 cu ft	62.4 lbs/cu ft
DOSAGE		
17.1 mg/*L*	= 1 grain/gal	17.1 mg/*L*/gpg
64.7 grains	= 1 mg	64.7 grains/mg
PRESSURE		
2.31 ft water	= 1 psi	2.31 ft water/psi
0.433 psi	= 1 ft water	0.433 psi/ft water
1.133 ft water	= 1 in Mercury	1.133 ft water/in Mercury
FLOW		
694 GPM	= 1 MGD	694 GPM/MGD
1.55 CFS	= 1 MGD	1.55 CFS/MGD
TIME		
60 sec	= 1 min	60 sec/min
60 min	= 1 hr	60 min/hr
24 hr	= 1 day	24 hr/day

NOTE: In our equations the values in the right hand column may be written either as 24 hr/day or 1 day/24 hours depending on which units we wish to convert or our desired results.

A.11 BASIC FORMULAS

FLOWS

1. $$\text{Flow, MGD} = \frac{(\text{Flow, GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}$$

or

$$\text{Flow, GPM} = \frac{(\text{Flow, MGD})(1{,}000{,}000)}{(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}$$

CHEMICAL DOSES

2. $$\text{Chemical Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})$$

Calibration of a Dry Chemical Feeder

3. $$\text{Chemical Feed, lbs/day} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

Calibration of a Solution Chemical Feeder (Chemical Feed Pump or a Hypochlorinator)

4. $$\text{Chemical Feed, lbs/day} = \frac{(\text{Chem Conc., mg}/L)(\text{Vol Pumped, m}L)(60\text{ min/hr})(24\text{ hr/day})}{(\text{Time Pumped, min})(1000\text{ m}L/L)(1000\text{ mg/gm})(454\text{ gm/lb})}$$

DISTRIBUTION SYSTEM FACILITIES

5. $$\text{Pressure Head, ft} = (\text{Pressure, psi})(2.31\text{ ft/psi})$$

6. $$\text{Pressure, psi} = \frac{(\text{Pressure Head, ft})}{2.31\text{ ft/psi}}$$

or

$$\text{Pressure, psi} = (\text{Pressure Head, ft})(0.433\text{ psi/ft})$$

7. $$\text{Flow, cu ft/sec} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

8. $$\text{Actual Leakage, GPD/mi-in} = \frac{\text{Leak Rate, GPD}}{(\text{Length, mi})(\text{Diameter, in})}$$

9. $$\text{Pressure, lbs/sq ft} = (62.4\text{ lbs/cu ft})(\text{Height or Water, ft})$$

9a. $$\text{Uplift Force, lbs} = (\text{Area sq, ft})(\text{Pressure, lbs/sq ft})$$

10. $$\text{Slope} = \frac{\text{Energy Loss, ft}}{\text{Distance, ft}}$$

11. $$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75\ (\text{Diameter, ft})^{2.63}(\text{Slope})^{0.54}}$$

DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

12. $$\text{Average} = \frac{\text{Sum of Measurements}}{\text{Number of Measurements}}$$

13. $$\text{Annual Running Average} = \frac{\text{Sum of All Averages}}{\text{Number of Averages}}$$

14. $$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

14a. $$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48\text{ gal/cu ft})(60\text{ sec/min})$$

15. $$\text{Volume, gal} = (\text{Area, sq ft})(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

15a. Flow, GPM $= \dfrac{\text{Volume, gal}}{\text{Time, min}}$

16. Meter Accuracy, % $= \dfrac{\text{(Meter Reading, GPM)(100\%)}}{\text{Actual Volume, GPM}}$

17. Meter Accuracy, % $= \dfrac{\text{(Meter Reading, gal)(100\%)}}{\text{Actual Volume, gal}}$

18. Volume, cu ft = (Length, ft)(Width, ft)(Depth, ft)

18a. Volume, cu yd $= \dfrac{\text{Volume, cu ft}}{\text{27 cu ft/cu yd}}$

19. Flow Volume, gal = (Flow Rate, gal/min)(Time, min)

20. Time to Fill, min $= \dfrac{\text{Total Volume, gal}}{\text{Flow Rate, gal/min}}$

21. Volume, gal/ft = (Area, sq ft)(7.48 gal/cu ft)

21a. Volume, gal = (Volume, gal/ft)(Depth, ft)

22. Flow, GPM $= \dfrac{\text{2.83 (Diameter, in)(Distance, in)}^2}{\sqrt{\text{Height, in}}}$

DISINFECTION

23. Chlorine, lbs = (Volume, M Gal)(Dose, mg/*L*)(8.34 lbs/gal)

23a. Sodium Hypochlorite Solution, gal $= \dfrac{\text{(Chlorine, lbs)(100\%)}}{\text{(8.34 lbs/gal)(Hypochlorite, \%)}}$

24. To disinfect a main use the same formulas as in 31 to disinfect a well.

25. To disinfect a storage tank use the same formulas as in 31 to disinfect a well.

26. Actual Dose, mg/*L* $= \dfrac{\text{Chlorine, lbs}}{\text{(Volume, of Water, M Gal)(8.34 lbs/gal)}}$

27. Chlorine Feed, lbs/day = (Flow, MGD)(Dose, mg/*L*)(8.34 lbs/gal)

28. Chlorine Demand, mg/*L* = Chlorine Dose, mg/*L*, − Chlorine Residual, mg/*L*

29. Hypochlorite, gal = (Container Area, sq ft)(Drawdown, ft)(7.48 gal/cu ft)

30. Hypochlorite Strength, % $= \dfrac{\text{(Chlorine Required, lbs/day)(100\%)}}{\text{(Hypochlorinator Flow, gal/day)(8.34 lbs/gal)}}$

31. Water Added, gal (to Hypochlorite Solution) $= \dfrac{\text{(Hypo, gal)(Hypo, \%)} - \text{(Hypo, gal)(Desired Hypo, \%)}}{\text{Desired Hypo, \%}}$

A.12 HOW TO USE THE BASIC FORMULAS

One clever way of using the basic formulas is to use the Davidson[1] Pie Method. To apply this method to the first basic formula,

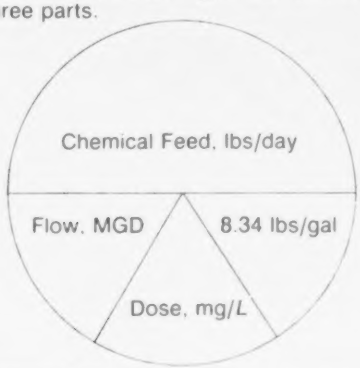
1. Chemical Feeder, lbs/day = (Flow, MGD)(Dose,mg/*L*)(8.34 lbs/gal)

(a) Draw a circle and draw a horizontal line through the middle of the circle;

(b) Write the Chemical Feed, lbs/day in the top half;

(c) Divide the bottom half into three parts; and

(d) Write Flow, MGD; Dose, mg/*L*, and 8.34 lbs/gal in the other three parts.



If you want to find the Chemical Feed, lbs/day, cover up the Chemical Feed, and what is left uncovered will give you the correct formula.

2. Chemical Feed, lbs/day = (Flow, MGD)(Dose, mg/*L*)(8.34 lbs/gal)

If you know the chlorinator setting in pounds per day and the flow in MGD and would like to know the dose in mg/*L*, cover up the Dose, mg/*L*, and what is left uncovered will give you the correct formula.

3. Dose, mg/*L* $= \dfrac{\text{Chemical Feed, lbs/day}}{\text{(Flow, MGD)(8.34 lbs/gal)}}$

Another approach to using the basic formulas is to memorize the basic formula, for example the detention time formula.

4. Detention Time, hr $= \dfrac{\text{(Tank Volume, gal)(24 hr/day)}}{\text{Flow, gal/day}}$

This formula works fine to solve for the detention time when the Tank Volume, gal, and Flow, gal/day, are given.

If you wish to determine the Flow, gal/day, when the Detention Time, hr, and Tank Volume, gal, are given, you must change the basic formula. You want the Flow, gal/day, on the left of the equal sign and everything else on the right of the equal sign. This is done by moving the terms diagonally (from top to bottom or from bottom to top) past the equal sign.

4. $\boxed{\text{Detention Time, hr}} = \dfrac{\text{(Tank Volume, gal)(24 hr/day)}}{\boxed{\text{Flow, gal/day}}}$

or

Flow, gal/day $= \dfrac{\text{(Tank Volume, gal)(24 hr/day)}}{\text{Detention Time, hr}}$

This same approach can be used if the Tank Volume, gal, was unknown and the Detention Time, hr, and Flow, gal/day, were given. We want Tank Volume, gal, on one side of the equation and everything else on the other side.

4. Detention Time, hr $= \dfrac{\text{(Tank Volume, gal)}\boxed{\text{(24 hr/day)}}}{\boxed{\text{Flow, gal/day}}}$

To Top

To Bottom

or

---

[1] Gerald Davidson, Manager, Clear Lake Oaks Water District, Clear Lake Oaks, California.

$$\frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{24\text{ hr/day}} = \text{Tank Volume, gal}$$

or

$$\text{Tank Volume, gal} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{24\text{ hr/day}}$$

One more check is to be sure the units in the rearranged formula cancel out correctly.

For additional information on the use of the basic formulas, refer to Sections:

A.91, "Selection of Formula,"

A.92, "Arrangement of Formula,"

A.93, "Unit Conversions," and

A.94, "Calculations."

A.13 TYPICAL WATER DISTRIBUTION SYSTEM PROBLEMS (ENGLISH SYSTEM)

A.130 Flows

EXAMPLE 1

Convert a flow of 450 gallons per minute to million gallons per day.

Known	Unknown
Flow, GPM = 450 GPM	Flow, MGD

Convert flow from 450 GPM to MGD.

$$\begin{aligned}\text{Flow, MGD} &= \frac{(\text{Flow, GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= \frac{(450\text{ GPM})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= 0.648\text{ MGD}\end{aligned}$$

A.131 Chemical Dose

EXAMPLE 2

Determine the chlorinator setting in pounds per 24 hours if a well pump delivers 300 GPM and the desired chlorine dose is 2.0 mg/*L*.

Known		Unknown
Flow, GPM	= 300 GPM	Chlorinator Setting, lbs/24 hours
Chlorine Dose, mg/*L*	= 2.0 mg/*L*	

1. Convert flow from gallons per minute to million gallons per day.

$$\begin{aligned}\text{Flow, MGD} &= \frac{(\text{Flow, gal/min})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= \frac{(300\text{ gal/min})(1\text{ Million})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000}\\ &= 0.432\text{ MGD}\end{aligned}$$

NOTE: When we multiply an equation by $\frac{1\text{ Million}}{1{,}000{,}000}$ we do not change anything except the units. This is just like multiplying an equation by 12 inches/foot or 60 min/hr; all we are doing is changing units.

2. Determine the chlorinator setting in pounds per 24 hours or pounds per day.

$$\begin{aligned}\text{Chemical Feed, lbs/day} &= (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\text{ lbs/gal})\\ &= (0.432\text{ MGD})(2.0\text{ mg}/L)(8.34\text{ lbs/gal})\\ &= 7.2\text{ lbs/day}\end{aligned}$$

EXAMPLE 3

Determine the actual chemical dose or chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 0.2 pounds empty and 2.6 pounds after 30 minutes.

Known		Unknown
Empty Bucket, lbs	= 0.2 lbs	Chemical Feed, lbs/day
Full Bucket, lbs	= 2.6 lbs	
Time to Fill, min	= 30 min	

Determine the chemical feed in pounds of chemical per day.

$$\begin{aligned}\text{Chemical Feed, lbs/day} &= \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, days}}\\ &= \frac{(2.6\text{ lbs} - 0.2\text{ lbs})(60\text{ min/hr})(24\text{ hr/day})}{30\text{ min}}\\ &= 115\text{ lbs/day}\end{aligned}$$

EXAMPLE 4

Determine the chemical feed in pounds of chlorine per day from a hypochlorinator. The hypochlorite solution is 1.4 percent or 14,000 mg chlorine per liter. During a test run the hypochlorinator delivers 400 m*L* during 12 minutes.

Known		Unknown
Cl Solution, %	= 1.4%	Chemical Feed, lbs/day
Cl Conc, mg/*L*	= 14,000 mg/*L*	
Vol Pumped, m*L*	= 400 m*L*	
Time Pumped, min	= 12 min	

Calculate the chlorine fed by the hypochlorinator in pounds of chlorine per day.

$$\begin{aligned}\text{Chlorine Feed, lbs/day} &= \frac{(\text{Cl Conc, mg}/L)(\text{Vol Pumped, m}L)(60\text{ min/hr})(24\text{ hr/day})}{(\text{Time Pumped, min})(1000\text{ m}L/L)(1000\text{ mg/gm})(454\text{ gm/lb})}\\ &= \frac{(14{,}000\text{ mg}/L)(400\text{ m}L)(60\text{ min/hr})(24\text{ hr/day})}{(12\text{ min})(1000\text{ m}L/L)(1000\text{ mg/gm})(454\text{ gm/lb})}\\ &= 1.48\text{ lbs/day}\\ \text{or } &= 1.5\text{ lbs chlorine/day}\end{aligned}$$

A.132 Distribution System Facilities

EXAMPLE 5

A pressure gage at a fire hydrant reads 50 psi. What is the pressure head on the gage at the fire hydrant in feet.

Known	Unknown
Pressure, psi = 50 psi	Pressure Head, ft

Convert the pressure in psi to pressure head in feet.

$$\begin{aligned}\text{Pressure Head, ft} &= (\text{Pressure, psi})(2.31\text{ ft/psi})\\ &= (50\text{ psi})(2.31\text{ ft/psi})\\ &= 115.5\text{ ft}\end{aligned}$$

EXAMPLE 6

A pressure gage on a fire hydrant reads 170 feet of pressure head. What is the pressure in psi?

Known	Unknown
Pressure Head, ft = 170 ft	Pressure, psi

Calculate the pressure head in pounds per square inch (psi).

$$\text{Pressure, psi} = \frac{\text{Pressure Head, ft}}{2.31 \text{ ft/psi}}$$

$$= \frac{170 \text{ ft}}{2.31 \text{ ft/psi}}$$

$$= 74 \text{ psi}$$

or

$$\text{Pressure, psi} = (\text{Pressure Head, ft})(0.433 \text{ psi/ft})$$

$$= (170 \text{ ft})(0.433 \text{ psi/ft})$$

$$= 74 \text{ psi}$$

EXAMPLE 7

A 6-inch diameter water main needs to be flushed with a water velocity of five feet per second. What should be the flow through the main in cubic feet per second and gallons per minute?

Known	Unknown
Diameter, in = 6 in	Flow, GPM
Velocity, ft/sec = 5 ft/sec	

1. Calculate the pipe area in square feet.

$$\text{Area, sq ft} = 0.785 (\text{Diameter, ft})^2$$

$$= \frac{0.785 (6 \text{ in})^2}{(12 \text{ in/ft})^2}$$

$$= 0.196 \text{ sq ft}$$

2. Determine the flow in cubic feet per second.

$$\text{Flow, cu ft/sec} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= (0.196 \text{ sq ft})(5 \text{ ft/sec})$$

$$= 0.98 \text{ cu ft/sec}$$

3. Convert the flow from cubic feet per second to gallons per minute. To do this use the proper conversion factors to change cubic feet to gallons and also seconds to minutes.

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= (0.98 \text{ cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})$$

$$= 440 \text{ GPM}$$

EXAMPLE 8

Determine the actual leakage in GPD/mi-in from a new section of pipe if the leak rate during the test period was 60 GPD. The section tested is one quarter of a mile (0.25 mi) long and the pipe diameter is 12 inches.

Known	Unknown
Leak Rate, GPD = 60 GPD	Actual Leakage, GPD/mi-in
Length, mi = 0.25 mi	
Diameter, in = 12 in	

Calculate the actual leakage from the test section in gallons per day per mile per inch of pipe diameter.

$$\text{Actual Leakage, GPD/mi-in} = \frac{\text{Leak Rate, GPD}}{(\text{Length, mi})(\text{Diameter, in})}$$

$$= \frac{60 \text{ GPD}}{(0.25 \text{ mi})(12 \text{ in})}$$

$$= 20 \text{ GPD/mi-in}$$

EXAMPLE 9

An underground rectangular water storage tank must be drained and cleaned. The tank is 30-feet long and 10-feet wide. The groundwater is five feet above the bottom of the tank. What is the force of the water pressure lifting upward on the bottom of the tank?

Known	Unknown
Length, ft = 30 ft	Uplift Force, lbs
Width, ft = 10 ft	
Height, ft = 5 ft	

1. Calculate the area of the tank bottom.

$$\text{Area, sq ft} = (\text{Length, ft})(\text{Width, ft})$$

$$= (30 \text{ ft})(10 \text{ ft})$$

$$= 300 \text{ sq ft}$$

2. Calculate the pressure on the bottom of the tank in pounds per square foot (lbs/sq ft).

$$\text{Pressure, lbs/sq ft} = (\text{Density of Water, lbs/cu ft})(\text{Height, ft})$$

$$= (62.4 \text{ lbs/cu ft})(5 \text{ ft})$$

$$= 312 \text{ lbs/sq ft}$$

3. Calculate the uplift force on the bottom of the tank.

$$\text{Uplift Force, lbs} = (\text{Area, sq ft})(\text{Pressure, lbs/sq ft})$$

$$= (300 \text{ sq ft})(312 \text{ lbs/sq ft})$$

$$= 93{,}600 \text{ lbs}$$

If the tank weighs less than 93,600 lbs, the tank will float when emptied if the groundwater is five feet or higher above the bottom of the tank.

EXAMPLE 10 (Advanced Problem)

Estimate the C Factor for a 10-inch water main. When the flow is 800 GPM, the drop in pressure head elevation between two pressure gages 500 feet apart is two feet.

Known	Unknown
Diameter, in = 10 in	C Factor
Flow, GPM = 800 GPM	
Energy Loss, ft = 2 ft	
Distance, ft = 500 ft	

1. Convert a diameter of 10 inches to feet.

$$\text{Diameter, ft} = \frac{\text{Diameter, in}}{12 \text{ in/ft}}$$

$$= \frac{10 \text{ in}}{12 \text{ in/ft}}$$

$$= 0.833 \text{ ft}$$

2. Calculate the slope.

$$\text{Slope} = \frac{\text{Energy Loss, ft}}{\text{Distance, ft}}$$

$$= \frac{2\text{ ft}}{500\text{ ft}}$$

$$= 0.004\text{ ft/ft}$$

3. Calculate the C Factor.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75\ (\text{Diameter, ft})^{2.63}(\text{Slope})^{0.54}}$$

$$= \frac{800\text{ GPM}}{193.75\ (0.833\text{ ft})^{2.63}(0.004)^{0.54}}$$

$$= \frac{800\text{ GPM}}{(193.75)(0.619)(0.0507)}$$

$$= 132$$

EXAMPLE 11 (Advanced Problem)

Estimate the C Factor for a 15-inch diameter pipe if a field test was conducted using a flow of 1500 GPM. A pressure gage at elevation 51.0 feet at a fire hydrant read 40 psi. Another pressure gage at elevation 50.0 feet at a fire hydrant read 39.8 psi. The fire hydrants are 800 feet apart.

Known		Unknown
Diameter, in	= 15 in	C Factor
Flow, GPM	= 1500 GPM	
GAGE NO. 1		
Elev, ft	= 51.0 ft	
Pres, psi	= 40 psi	
GAGE NO. 2		
Elev, ft	= 50.0 ft	
Pres, psi	= 39.8 psi	
Distance, ft	= 800 ft	

1. Determine the elevations of the pressure heads at gages 1 and 2.

GAGE NO. 1

$$\text{Elev Pres Head, ft} = 51.0\text{ ft} + (40\text{ psi})(2.31\text{ ft/psi})$$

$$= 143.4\text{ ft}$$

GAGE NO. 2

$$\text{Elev Pres Head, ft} = 50.0\text{ ft} + (39.8\text{ psi})(2.31\text{ ft/psi})$$

$$= 141.9\text{ ft}$$

2. Determine the slope of the energy grade line.

$$\text{Slope} = \frac{\text{Difference in Elev Pres Head, ft}}{\text{Distance, ft}}$$

$$= \frac{143.4\text{ ft} - 141.9\text{ ft}}{800\text{ ft}}$$

$$= \frac{1.5\text{ ft}}{800\text{ ft}}$$

$$= 0.001875\text{ ft/ft}$$

3. Calculate the C Factor.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75(\text{Diameter, ft})^{2.63}(\text{Slope})^{0.54}}$$

$$= \frac{1500\text{ GPM}}{193.75(15\text{ in}/12\text{ in/ft})^{2.63}(0.001875)^{0.54}}$$

$$= \frac{1500\text{ GPM}}{(193.75)(1.798)(0.03368)}$$

$$= 128$$

A.133 Distribution System Operation and Maintenance

EXAMPLE 12

Calculate the quarterly average TTHM (Total Trihalomethane) for a water supply system in micrograms per liter based on the results of tests taken during a three-month period.

Test Number	1	2	3	4	5	6
TTHM, $\mu g/L$	140	100	80	160	150	90

Known	Unknown
Test Results Shown Above	Average TTHM, $\mu g/L$

$$\text{Ave. TTHM, }\mu g/L = \frac{\text{Sum of Measurements, }\mu g/L}{\text{Number of Measurements}}$$

$$= \frac{140 + 100 + 80 + 160 + 150 + 90}{6}$$

$$= \frac{720\ \mu g/L}{6}$$

$$= 120\ \mu g/L$$

$$= 0.12\text{ mg}/L$$

EXAMPLE 13

Determine the annual running TTHM average using the quarterly results shown below.

Known	Unknown
Results from Quarterly TTHM Analyses	Annual Running TTHM Average, mg/L

YEAR 1

QUARTER	*CONC, mg/L*
1	0.07
2	0.09
3	0.12
4	0.08

YEAR 2

QUARTER	*CONC, mg/L*
1	0.09
2	0.11
3	0.13
4	0.07

Calculate the annual running TTHM average for each quarter during Year 2. Use the quarterly TTHM average for the quarter being considered and the three quarters immediately before the one being considered.

YEAR 2, QUARTER 1

$$\text{Annual Running TTHM Average, mg}/L = \frac{\text{Sum of Measurements, mg}/L}{\text{Number of Measurements}}$$

$$= \frac{0.09\text{ mg}/L + 0.08\text{ mg}/L + 0.12\text{ mg}/L + 0.09\text{ mg}/L}{4}$$

$$= \frac{0.38\text{ mg}/L}{4}$$

$$= 0.095\text{ mg}/L$$

YEAR 2, QUARTER 2

$$\text{Annual Running TTHM Average, mg}/L = \frac{0.11\text{ mg}/L + 0.09\text{ mg}/L + 0.08\text{ mg}/L + 0.12\text{ mg}/L}{4}$$

$$= \frac{0.40\text{ mg}/L}{4}$$

$$= 0.10\text{ mg}/L$$

YEAR 2, QUARTER 3

$$\text{Annual Running TTHM Average, mg}/L = \frac{0.13\text{ mg}/L + 0.11\text{ mg}/L + 0.09\text{ mg}/L + 0.08\text{ mg}/L}{4}$$

$$= \frac{0.41\text{ mg}/L}{4}$$

$$= 0.103\text{ mg}/L$$

YEAR 2, QUARTER 4

$$\text{Annual Running TTHM Average, mg}/L = \frac{0.07\text{ mg}/L + 0.13\text{ mg}/L + 0.11\text{ mg}/L + 0.09\text{ mg}/L}{4}$$

$$= \frac{0.40\text{ mg}/L}{4}$$

$$= 0.10\text{ mg}/L$$

EXAMPLE 14

An 18-inch diameter water main is to be flushed at a velocity of 4 ft/sec. What should be the reading on the flow meter in gallons per minute?

Known		Unknown
Diameter, in	= 18 in	Flow, GPM
Velocity, ft/sec	= 4 ft/sec	

1. Calculate the cross-sectional area of the pipe in square feet.

$$\text{Area, sq ft} = \frac{(0.785)(\text{Diameter, in})^2}{144\text{ sq in/sq ft}}$$

$$= \frac{(0.785)(18\text{ in})^2}{144\text{ sq in/sq ft}}$$

$$= 1.77\text{ sq ft}$$

2. Determine the flow in the pipe in cubic feet per second (CFS). Use Q = AV.

$$\text{Flow, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= (1.77\text{ sq ft})(4\text{ ft/sec})$$

$$= 7.1\text{ CFS}$$

3. Calculate the flow meter reading in gallons per minute (GPM).

$$\text{Flow, GPM} = (\text{Flow, cu ft/sec})(7.48\text{ gal/cu ft})(60\text{ sec/min})$$

$$= (7.1\text{ cu ft/sec})(7.48\text{ gal/cu ft})(60\text{ sec/min})$$

$$= 3186\text{ GPM}$$

EXAMPLE 15

During a 20 minute time span the water in a tank three feet in diameter increases by four feet. Calculate the total flow in gallons and the flow in gallons per minute.

Known		Unknown
Time, min	= 20 min	1. Volume, gal
Diameter, ft	= 3 ft	2. Flow, GPM
Depth, ft	= 4 ft	

1. Calculate the total flow in gallons.

$$\text{Volume, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

$$= (0.785)(3\text{ ft})^2(4\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 211\text{ gal}$$

2. Calculate the flow in gallons per minute.

$$\text{Flow, GPM} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$= \frac{211\text{ gal}}{20\text{ min}}$$

$$= 10.6\text{ GPM}$$

EXAMPLE 16

A water meter is tested in a laboratory. The meter reads 1.3 GPM and the actual flow was 1.33 GPM. Determine the meter accuracy as a percentage.

Known		Unknown
Meter Reading, GPM	= 1.3 GPM	Meter Accuracy, %
Actual Flow, GPM	= 1.33 GPM	

Determine the meter accuracy as a percentage.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, GPM})(100\%)}{\text{Actual Flow, GPM}}$$

$$= \frac{(1.3\text{ GPM})(100\%)}{1.33\text{ GPM}}$$

$$= 97.7\%$$

EXAMPLE 17

A water meter is tested in a laboratory. The meter reads 260 gallons. The actual flow was measured in a volumetric measuring tank three feet in diameter. During the meter test five feet of water was added to the tank. Determine the meter accuracy as a percentage.

Known		Unknown
Meter Reading, gal	= 260 gal	Meter Accuracy, %
Diameter, ft	= 3 ft	
Depth, ft	= 5 ft	

1. Calculate the actual volume of water which flowed through the meter in gallons.

$$\text{Volume, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

$$= (0.785)(3\text{ ft})^2(5\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 264\text{ gal}$$

2. Determine the meter accuracy as a percentage.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, gal})(100\%)}{\text{Actual Volume, gal}}$$

$$= \frac{(260\text{ gal})(100\%)}{264\text{ gal}}$$

$$= 98.5\%$$

EXAMPLE 18

A trench four-feet wide, 1100-feet long and six-feet deep is to be excavated for a water main. How many cubic feet and also cubic yards of soil have to be excavated for the water main?

Known	Unknown
Length, ft = 1100 ft	1. Volume Excavated, cu ft
Width, ft = 4 ft	2. Volume Excavated, cu yd
Depth, ft = 6 ft	

1. Calculate the volume excavated in cubic feet.

$$\text{Volume, cu ft} = (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})$$

$$= (1100\text{ ft})(4\text{ ft})(6\text{ ft})$$

$$= 26{,}400\text{ cu ft}$$

2. Calculate the volume excavated in cubic yards.

$$\text{Volume, cu yd} = \frac{\text{Volume, cu ft}}{27\text{ cu ft/cu yd}}$$

$$= \frac{26{,}400\text{ cu ft}}{27\text{ cu ft/cu yd}}$$

$$= 978\text{ cu yd}$$

EXAMPLE 19

A flow meter indicates a flow rate of seven gallons per minute. How many gallons of water will flow through the meter in three hours and 30 minutes?

Known	Unknown
Flow Rate, GPM = 7 GPM	Flow Volume, gal
Time, hr = 3 hr & 30 min	

1. Convert three hours and 30 minutes to hours.

$$\text{Time, hr} = 3\text{ hr} + \frac{30\text{ min}}{60\text{ min/hr}}$$

$$= 3\text{ hr} + 0.5\text{ hr}$$

$$= 3.5\text{ hr}$$

2. Calculate the total flow volume of water in gallons.

$$\text{Flow Volume, gal} = (\text{Flow Rate, gal/min})(\text{Time, hr})(60\text{ min/hr})$$

$$= (7\text{ gal/min})(3.5\text{ hr})(60\text{ min/hr})$$

$$= 1470\text{ gal}$$

EXAMPLE 20

A chemical solution tank is 4. 5 feet in diameter and five-feet deep. How long will it take to fill this tank when water flows in at a rate of 3.6 gallons per minute?

Known	Unknown
Diameter, ft = 4.5 ft	Time to Fill, min
Depth, ft = 5 ft	
Flow Rate, GPM = 3.6 GPM	

1. Calculate the tank volume in gallons.

$$\text{Tank Volume, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

$$= (0.785)(4.5\text{ ft})^2(5\text{ ft})(7.48\text{ gal/cu ft})$$

$$= 595\text{ gal}$$

2. Calculate the time to fill the tank in minutes.

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

$$= \frac{595\text{ gal}}{3.6\text{ gal/min}}$$

$$= 165\text{ min}$$

3. Convert 165 minutes to hours and minutes.

$$\text{Time to Fill} = \frac{165\text{ min}}{60\text{ min/hr}}$$

$$= 2.75\text{ hr}$$

$$= 2\text{ hr} + (0.75\text{ hr})(60\text{ min/hr})$$

$$= 2\text{ hr} + 45\text{ min}$$

EXAMPLE 21

A cylindrical water storage tank is 30 feet in diameter and 15 feet high. Calculate the gallons of water per foot of depth and then the total gallons when the water is 11.6 feet deep.

Known	Unknown
Diameter, ft = 30 ft	1. Volume, gal/ft
Height, ft = 15 ft	2. Volume, gal (for Depth = 11.6 ft)
Depth, ft = 11.6 ft	

1. Calculate the volume of water in the tank per foot of depth.

$$\text{Volume, gal} = (\text{Area, sq ft})(\text{Depth, ft})(7.48\text{ gal/cu ft})$$

$$\text{Volume, gal/ft} = (0.785)(\text{Diameter, ft})^2(7.48\text{ gal/cu ft})$$

$$= (0.785)(30\text{ ft})^2(7.48\text{ gal/cu ft})$$

$$= 5285\text{ gal/ft}$$

2. Calculate the volume of water in the tank in gallons when the water is 11.6 feet deep in the tank.

$$\text{Volume, gal} = (\text{Volume, gal/ft})(\text{Depth, ft})$$

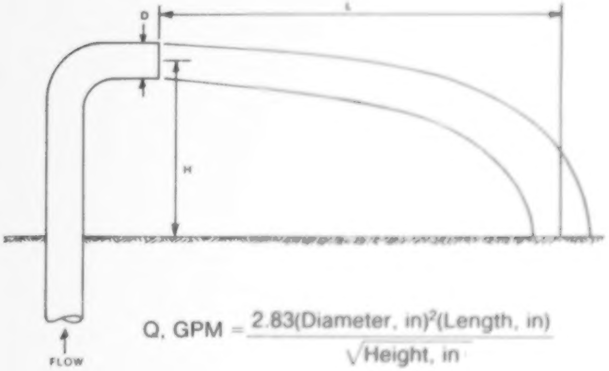
$$= (5285\text{ gal/ft})(11.6\text{ ft})$$

$$= 61{,}306\text{ gallons}$$

EXAMPLE 22

Estimate the flow from a pipe in gallons per minute. Water is flowing from a two-inch diameter pipe. The pipe is 36 inches above the point where the water hits the ground. The water hits the ground 60 inches (horizontal distance) from where the water leaves the pipe. See Figure A.3 for a sketch of this problem.

Known	**Unknown**
Diameter, in = 2 in	Flow, GPM
Height, in = 36 in	
Distance, in = 60 in	



$$Q,\ \text{GPM} = \frac{2.83(\text{Diameter, in})^2(\text{Length, in})}{\sqrt{\text{Height, in}}}$$

Fig. A.3 Sketch of flow from a hydrant

Estimate the flow from the pipe in gallons per minute.

$$\text{Flow, GPM} = \frac{2.83(\text{Diameter, in})^2(\text{Distance, in})}{\sqrt{\text{Height, in}}}$$

$$= \frac{2.83(2\ \text{in})^2(60\ \text{in})}{\sqrt{36\ \text{in}}}$$

$$= 113\ \text{GPM}$$

A.134 Disinfection

EXAMPLE 23

How many gallons of five percent sodium hypochlorite will be needed to disinfect a well with a 15-inch diameter casing and well screen? The well is 180 feet deep and there is 75 feet of water in the well. Use an initial chlorine dose of 100 mg/*L*.

Known	**Unknown**
Hypochlorite, % = 5%	5% Hypochlorite, gal
Chlorine Dose, mg/*L* = 100 mg/*L*	
Diameter, in = 15 in	
Well Depth, ft = 180 ft	
Water Depth, ft = 75 ft	

1. Calculate the volume of water in the well in gallons.

$$\text{Water Vol, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$= \frac{(0.785)(15\ \text{in})^2(75\ \text{ft})(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

$$= 688\ \text{gal}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.000688\ \text{M Gal})(100\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 0.57\ \text{lbs chlorine}$$

3. Calculate the gallons of five percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gal} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}$$

$$= \frac{(0.57\ \text{lbs})(100\%)}{(8.34\ \text{lbs/gal})(5\%)}$$

$$= 1.37\ \text{gallons}$$

Use 1.4 gallons of five percent sodium hypochlorite to disinfect the well.

EXAMPLE 24

A new 10-inch diameter water main 650-feet long needs to be disinfected. An initial chlorine dose of 400 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution will be needed?

Known	**Unknown**
Diameter of Pipe, in = 10 in	5.25% Hypochlorite, gal
Length of Pipe, ft = 650 ft	
Chlorine Dose, mg/*L* = 400 mg/*L*	
Hypochlorite, % = 5.25%	

1. Calculate the volume of water in the pipe in gallons.

$$\text{Pipe Volume, gal} = (0.785)(\text{Diameter, ft})^2(\text{Length, ft})(7.48\ \text{gal/cu ft})$$

$$= \frac{(0.785)(10\ \text{in})^2(650\ \text{ft})(7.48\ \text{gal/cu ft})}{144\ \text{sq in/sq ft}}$$

$$= 2650\ \text{gal}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.00265\ \text{M Gal})(400\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 8.84\ \text{lbs chlorine}$$

3. Calculate the gallons of 5.25 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}$$

$$= \frac{(8.84\ \text{lbs})(100\%)}{(8.34\ \text{lbs/gal})(5.25\%)}$$

$$= 20.2\ \text{gallons}$$

EXAMPLE 25

A service storage reservoir has been taken out of service for inspection, maintenance and repairs. The reservoir needs to be disinfected before being placed back on line. The reservoir is 30 feet in diameter and 8-feet deep. An initial chlorine dose of 100 mg/*L* is expected to maintain a chlorine residual of over 50 mg/*L* during the 24-hour disinfection period. How many gallons of 15 percent sodium hypochlorite solution will be needed?

Known	**Unknown**
Diameter, ft = 30 ft	15% Hypochlorite, gal
Tank Depth, ft = 8 ft	
Chlorine Dose, mg/*L* = 100 mg/*L*	
Hypochlorite, % = 15%	

1. Calculate the volume of water in the tank in gallons.

$$\text{Tank Volume, gal} = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(30\ \text{ft})^2(8\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 42{,}277\ \text{gal}$$

2. Determine the pounds of chlorine needed.

$$\text{Chlorine, lbs} = (\text{Volume, M Gal})(\text{Dose, mg/}L)(8.34\ \text{lbs/gal})$$

$$= (0.042277\ \text{M Gal})(100\ \text{mg/}L)(8.34\ \text{lbs/gal})$$

$$= 35.3\ \text{lbs chlorine}$$

3. Calculate the gallons of 15 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Sodium, gallons} = \frac{(\text{Chlorine, lbs})(100\%)}{(8.34\ \text{lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(35.3\ \text{lbs})(100\%)}{(8.34\ \text{lbs/gal})(15\%)}$$

$$= 28.2\ \text{gallons}$$

EXAMPLE 26

Calculate the actual chlorine dose in milligrams per liter if 200 gallons of a two percent sodium hypochlorite solution were used to treat two million gallons of water.

Known		Unknown
Volume Hypocl, gal	= 200 gal	Chlorine Dose, mg/*L*
Volume Water, M Gal	= 2 M Gal	
Hypochlorite, %	= 2%	

1. Calculate the pounds of chlorine used.

$$\text{Chlorine, lbs} = \frac{(\text{Hypochlorite, gal})(8.34\ \text{lbs/gal})(\text{Hypochlorite, }\%)}{100\%}$$

$$= \frac{(200\ \text{gal})(8.34\ \text{lbs/gal})(2\%)}{100\%}$$

$$= 33.36\ \text{lbs chlorine}$$

2. Calculate the actual chlorine dose in milligrams per liter.

$$\text{Actual Dose, mg/}L = \frac{\text{Chlorine, lbs}}{(\text{Volume Water, M Gal})(8.34\ \text{lbs/gal})}$$

$$= \frac{33.36\ \text{lbs chlorine}}{(2\ \text{M Gal})(8.34\ \text{lbs/gal})}$$

$$= 2.0\ \text{mg/}L$$

EXAMPLE 27

A deep-well turbine pump delivers 250 GPM against typical operating heads. If the desired chlorine dose is 2.5 mg/*L*, what should be the chlorine feed rate in pounds per day?

Known		Unknown
Flow, GPM	= 250 GPM	Chlorine Feed, lbs/day
Dose, mg/*L*	= 2.5 mg/*L*	

1. Convert flow from gallons per minute to million gallons per day.

$$\text{Flow, MGD} = \frac{(\text{Flow, GPM})(1\ \text{Million})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000}$$

$$= \frac{(250\ \text{GPM})(1\ \text{Million})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000}$$

$$= 0.36\ \text{MGD}$$

2. Calculate the chlorine feed rate in pounds of chlorine per day.

$$\text{Chlorine Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg/}L)(8.34\ \text{lbs/gal})$$

$$= (0.36\ \text{MGD})(2.5\ \text{mg/}L)(8.34\ \text{lbs/gal})$$

$$= 7.5\ \text{lbs/day}$$

EXAMPLE 28

Estimate the chlorine demand for a water in milligrams per liter if the chlorine dose is 2.6 mg/*L* and the chlorine residual is 0.4 mg/*L*.

Known		Unknown
Chlorine Dose, mg/*L*	= 2.6 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual, mg/*L*	= 0.4 mg/*L*	

Estimate the chlorine demand in milligrams per liter.

$$\text{Chlorine Demand, mg/}L = \text{Chlorine Dose, mg/}L - \text{Chlorine Residual, mg/}L$$

$$= 2.6\ \text{mg/}L - 0.4\ \text{mg/}L$$

$$= 2.2\ \text{mg/}L$$

EXAMPLE 29

Estimate the gallons of hypochlorite pumped by a hypochlorinator if the hypochlorite solution is in a container with a diameter of three feet and the hypochlorite level drops 18 inches (1.5 feet) during a specific time period.

Known		Unknown
Diameter, ft	= 3 ft	Hypochlorite Pumped, gal
Drop, ft	= 1.5 ft	

Estimate the gallons of hypochlorite pumped.

$$\text{Hypochlorite, gal} = (\text{Container Area, sq ft})(\text{Drop, ft})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(3\ \text{ft})^2(1.5\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 79.3\ \text{gallons}$$

EXAMPLE 30

Estimate the desired strength (as a percent chlorine) of a hypochlorite solution being pumped by a hypochlorinator that delivers 80 gallons per day. The water being treated requires a chlorine feed rate of ten pounds of chlorine per day.

Known		Unknown
Hypochlorinator Flow, GPD	= 80 GPD	Hypochlorite Strength, %
Chlorine Required, lbs/day	= 10 lbs/day	

Estimate the desired hypochlorite strength as a percent chlorine.

$$\text{Hypochlorite Strength, \%} = \frac{(\text{Chlorine Required, lbs/day})(100\%)}{(\text{Hypochlorinator Flow, gal/day})(8.34\ \text{lbs/gal})}$$

$$= \frac{(10\ \text{lbs/day})(100\%)}{(80\ \text{GPD})(8.34\ \text{lbs/gal})}$$

$$= 1.5\%$$

EXAMPLE 31

How many gallons of water must be added to ten gallons of a five percent hypochlorite solution to produce a 1.5 percent hypochlorite solution?

Known		Unknown
Hypochlorite, gal	= 10 gal	Water Added, gal
Desired Hypochlorite, %	= 1.5%	
Actual Hypochlorite, %	= 5%	

Calculate the gallons of water that must be added to produce a 1.5 percent hypochlorite solution.

$$\text{Water Added, gal (to hypochlorite solution)} = \frac{(\text{Hypo, gal})(\text{Hypo, \%}) - (\text{Hypo, gal})(\text{Desired Hypo, \%})}{\text{Desired Hypo, \%}}$$

$$= \frac{(10\ \text{gal})(5\%) - (10\ \text{gal})(1.5\%)}{1.5\%}$$

$$= \frac{50 - 15}{1.5}$$

$$= 23.3\ \text{gallons}$$

A.14 BASIC CONVERSION FACTORS (METRIC SYSTEM)

LENGTH		
100 cm	= 1 m	100 cm/m
3.281 ft	= 1 m	3.281 ft/m
AREA		
2.4711 ac	= 1 ha*	2.4711 ac/ha
10,000 sq m	= 1 ha	10,000 sq m/ha
VOLUME		
1000 m*L*	= 1 liter	1000 m*L*/*L*
1000 *L*	= 1 cu m	1000 *L*/cu m
3.785 *L*	= 1 gal	3.785 *L*/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
DENSITY		
1 kg	= 1 liter	1 kg/*L*
PRESSURE		
10.015 m	= 1 kg/sq cm	10.015 m/kg/sq cm
1 Pascal	= 1 N/sq m	1 Pa/N/sq m
1 psi	= 6895 Pa	1 psi/6895 Pa
FLOW		
3785 cu m/day	= 1 MGD	3785 cu m/day/MGD
3.785 M*L*/day	= 1 MGD	3.785 M*L*/day/MGD

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*hectare

A.15 TYPICAL WATER DISTRIBUTION SYSTEM PROBLEMS (METRIC SYSTEM)

A.150 Flows

EXAMPLE 1

Convert a flow of 500 gallons per minute to liters per second and cubic meters per day.

Known		Unknown
Flow, GPM	= 500 GPM	1. Flow, liters/sec 2. Flow, cu m/day

1. Convert the flow from 500 GPM to liters per second.

$$\text{Flow, liters/sec} = \frac{(\text{Flow, gal/min})(3.785\ \text{liters/gal})}{60\ \text{sec/min}}$$

$$= \frac{(500\ \text{gal/min})(3.785\ \text{liters/gal})}{60\ \text{sec/min}}$$

$$= 31.5\ \text{liters/sec}$$

2. Convert the flow from 500 GPM to cubic meters per day.

$$\text{Flow, cu m/day} = \frac{(\text{Flow, gal/min})(3.785\ L/\text{gal})(60\ \text{min/hr})(24\ \text{hr/day})}{1000\ L/\text{cu m}}$$

$$= \frac{(500\ \text{gal/min})(3.785\ L/\text{gal})(60\ \text{min/hr})(24\ \text{hr/day})}{1000\ L\ \text{cu/m}}$$

$$= 2725\ \text{cu m/day}$$

A.151 Chemical Doses

EXAMPLE 2

Determine the chlorinator setting in kilograms per 24 hours if 4000 cubic meters of water per day are to be treated with a desired chlorine dose of 2.5 mg/*L*.

Known		Unknown
Flow, cu m/day	= 4000 cu m/day	Chlorinator Setting, kg/24 hours
Chlorine Dose, mg/*L*	= 2.5 mg/*L*	

Determine the chlorinator setting in kilograms per 24 hours.

$$\text{Chlorinator Setting, kg/day} = \frac{(\text{Flow, cu m/day})(\text{Dose, mg}/L)(1{,}000\ L/\text{cu m})}{(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= \frac{(4000\ \text{cu m/day})(2.5\ \text{mg}/L)(1{,}000\ L/\text{cu m})}{(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= 10\ \text{kg/day}$$

EXAMPLE 3

Determine the actual dose or chemical feed in kilograms per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 100 grams empty and 1400 grams after 30 minutes.

Known		Unknown
Empty Bucket, gm	= 100 gm	Chemical Feed, kg/day
Full Bucket, gm	= 1400 gm	
Time to fill, min	= 30 min	

Determine the chemical feed in kilograms of chemical per day.

$$\text{Chemical Feed, kg/day} = \frac{\text{Chemical Applied, kg}}{\text{Length of Application, days}}$$

$$= \frac{(1400\ \text{gm} - 100\ \text{gm})(60\ \text{min/hr})(24\ \text{hr/day})}{(1000\ \text{gm/kg})(30\ \text{min})}$$

$$= 62.4\ \text{kg/day}$$

EXAMPLE 4

Determine the chemical feed in kilograms of chlorine per day from a hypochlorinator. The hypochlorite solution is 1.4 percent or 14,000 mg chlorine per liter. During a test run the hypochlorinator delivered 400 m*L* during 12 minutes.

Known	Unknown
Cl Solution, % = 1.4%	Chemical Feed, kg/day
Cl Conc, mg/*L* = 14,000 mg/*L*	
Vol Pumped, m*L* = 400 m*L*	
Time Pumped, min = 12 min	

Calculate the chlorine fed by the hypochlorinator in kilograms of chlorine per day.

$$\text{Chlorine Feed, kg/day} = \frac{(\text{Cl Conc, mg}/L)(\text{Vol Pumped, m}L)(60\text{ min/hr})(24\text{ hr/day})}{(\text{Time Pumped, min})(1000\text{ m}L/L)(1000\text{ mg/gm})(1000\text{ gm/kg})}$$

$$= \frac{(14{,}000\text{ mg}/L)(400\text{ m}L)(60\text{ min/hr})(24\text{ hr/day})}{(12\text{ min})(1000\text{ m}L/L)(1000\text{ mg/gm})(1000\text{ gm/kg})}$$

$$= 0.67\text{ kg/day}$$

A.152 Distribution System Facilities

EXAMPLE 5

A pressure gage at a fire hydrant reads 350 kiloPascals (kPa). What is the pressure head on the gage at the fire hydrant in meters?

Known	Unknown
Pressure, kPa = 350 kPa	Pressure Head, m

Convert the pressure from kPa to meters of head.

$$\text{Pressure Head, m} = (\text{Pressure, kPa})(0.102\text{ m/kPa})$$
$$= (350\text{ kPa})(0.102\text{ m/kPa})$$
$$= 35.7\text{ m}$$

EXAMPLE 6

A pressure gage on a fire hydrant reads 50 meters. What is the pressure in kiloPascals?

Known	Unknown
Pressure Head, m = 50 m	Pressure, kPa

Calculate the pressure head in kiloPascals.

$$\text{Pressure, kPa} = (\text{Pressure Head, m})(9.79\text{ kPa/m})$$
$$= (50\text{ m})(9.79\text{ kPa/m})$$
$$= 490\text{ kPa}$$

or

$$\text{Pressure, kPa} = \frac{\text{Pressure Head, m}}{0.102\text{ m/kPa}}$$
$$= \frac{50\text{ m}}{0.102\text{ m/kPa}}$$
$$= 490\text{ kPa}$$

EXAMPLE 7

A 100 mm-diameter water main needs to be flushed with a water velocity of 1.5 meters per second. What should be the flow through the main in cubic meters per second and liters per second?

Known	Unknown
Pipe Diameter, mm = 100 mm	Flow, cu m/sec
Velocity, m/sec = 1.5 m/sec	

1. Calculate the pipe area in square meters.

$$\text{Area, sq m} = (0.785)(\text{Diameter, m})^2$$
$$= (0.785)(0.1\text{ m})^2$$
$$= 0.00785\text{ sq m}$$

2. Determine the flow in cubic meters per second.

$$\text{Flow, cu m/sec} = (\text{Area, sq m})(\text{Velocity, m/sec})$$
$$= (0.00785\text{ sq m})(1.5\text{ m/sec})$$
$$= 0.0118\text{ cu m/sec}$$

3. Convert the flow from cubic meters per second to liters per second.

$$\text{Flow, liters/sec} = (\text{Flow, cu m/sec})(1000\ L/\text{cu m})$$
$$= (0.0118\text{ cu m/sec})(1000\ L/\text{cu m})$$
$$= 11.8\ L/\text{sec}$$

EXAMPLE 8

Determine the actual leakage in liters per day per kilometer per millimeter of diameter from a new section of pipe if the leak rate during the test period was 200 liters per day. The section tested is 0.4 kilometers long and the pipe diameter is 300 millimeters.

Known	Unknown
Leak Rate, *L*day = 200 *L*/day	Actual Leakage, *L*/day/km-mm
Length, km = 0.4 km	
Diameter, mm = 300 mm	

Calculate the actual leakage from the test section in liters per day per kilometer per millimeter of pipe diameter.

$$\text{Actual Leakage, } L\text{/day/km-mm} = \frac{\text{Leak Rate, } L\text{day}}{(\text{Length, km})(\text{Diameter, mm})}$$
$$= \frac{200\ L/\text{day}}{(0.4\text{ km})(300\text{ mm})}$$
$$= 1.67\text{ liters per day/km-mm}$$

EXAMPLE 9

An underground rectangular water storage tank must be drained and cleaned. The tank is 10-meters long and 3-meters wide. The groundwater is 2 meters above the bottom of the tank. What is the force of the water pressure lifting upward on the bottom of the tank?

Known	Unknown
Length, ft = 10 m	Uplift Force, kg
Width, ft = 3 m	
Height, ft = 2 m	

1. Calculate the area of the tank bottom.

$$\text{Area, sq m} = (\text{Length, m})(\text{Width, m})$$
$$= (10\text{ m})(3\text{ m})$$
$$= 30\text{ sq m}$$

2. Calculate the pressure on the bottom of the tank in kilograms per square meter (kg/sq m).

$$\text{Pressure, kg/sq m} = (\text{Density of Water, kg/cu m})(\text{Height, m})$$
$$= (1000 \text{ kg/cu m})(2 \text{ m})$$
$$= 2000 \text{ kg/sq m}$$

3. Calculate the uplift force on the bottom of the tank.

$$\text{Uplift Force, kg} = (\text{Area, sq m})(\text{Pressure, kg/sq m})$$
$$= (30 \text{ sq m})(2000 \text{ kg/sq m})$$
$$= 60{,}000 \text{ kg}$$

If the tank weighs less than 60,000 kg, the tank will float when emptied if the groundwater is two meters or higher above the bottom of the tank.

EXAMPLE 10 (Advanced Problem)

Estimate the C Factor for a 250-mm diameter water main. When the flow is 5 M*L*D (mega or million liters per day), the drop in pressure head elevation between two pressure gages 400 meters apart is two meters.

Known		Unknown
Diameter mm	= 250 mm = 0.25 m	C Factor
Flow, M*L*D	= 5 M*L*D	
Energy Loss, m	= 2 m	
Distance, m	= 400 m	

1. Calculate the slope.

$$\text{Slope} = \frac{\text{Energy Loss, m}}{\text{Distance, m}}$$
$$= \frac{2 \text{ m}}{400 \text{ m}}$$
$$= 0.005$$

2. Calculate the C Factor.

$$\text{C Factor} = \frac{\text{Flow, M}L\text{D}}{23.97\,(\text{Diameter, m})^{2.63}(\text{Slope})^{0.54}}$$
$$= \frac{5 \text{ M}L\text{D}}{(23.97)(0.25 \text{ m})^{2.63}(0.005)^{0.54}}$$
$$= \frac{5}{(23.97)(0.026)(0.057)}$$
$$= 141$$

EXAMPLE 11 (Advanced Problem)

Estimate the C Factor for a 400-mm diameter pipe if a field test was conducted using a flow of 100 liters per second. The difference in elevation of the pressure heads between two fire hydrants 250 meters apart is 0.5 meters.

Known		Unknown
Diameter, mm	= 400 mm	C Factor
Flow, *L*/sec	= 100 *L*/sec	
Pres Head Dif, m	= 0.5 m	
Distance, m	= 250 m	

1. Determine the slope of the energy grade line.

$$\text{Slope} = \frac{\text{Difference in Elev Pres Head, ft}}{\text{Distance, ft}}$$
$$= \frac{0.5 \text{ m}}{250 \text{ m}}$$
$$= 0.002$$

2. Calculate the C Factor.

$$\text{C Factor} = \frac{\text{Flow, } L\text{/sec}}{277.8(\text{Diameter, m})^{2.63}(\text{Slope})^{0.54}}$$
$$= \frac{100 \ L\text{/sec}}{277.8(0.4 \text{ m})^{2.63}(0.002)^{0.54}}$$
$$= \frac{100 \ L\text{/sec}}{(277.8)(0.0898)(0.03488)}$$
$$= 115$$

A.153 Distribution System Operation and Maintenance

EXAMPLE 12

Calculate the quarterly average TTHM (Total Trihalomethane) for a water supply system in micrograms per liter based on the results of tests taken during a three-month period.

Test Number	1	2	3	4	5	6
TTHM, $\mu g/L$	140	100	80	160	150	90

Known	Unknown
Test Results Shown Above	Average TTHM, $\mu g/L$

$$\text{Ave TTHM, } \mu g/L = \frac{\text{Sum of Measurements, } \mu g/L}{\text{Number of Measurements}}$$
$$= \frac{140 + 100 + 80 + 160 + 150 + 90}{6}$$
$$= \frac{720 \ \mu g/L}{6}$$
$$= 120 \ \mu g/L$$

EXAMPLE 13

Determine the annual running TTHM average using the quarterly results shown below.

Known	Unknown
Results from Quarterly TTHM Analyses	Annual Running TTHM Average, mg/L

YEAR 1

QUARTER	*CONC, mg/L*
1	0.07
2	0.09
3	0.12
4	0.08

YEAR 2

QUARTER	*CONC, mg/L*
1	0.09
2	0.11
3	0.13
4	0.07

Calculate the annual running TTHM average for each quarter during Year 2. Use the quarterly TTHM average for the quarter being considered and the three quarters immediately before the one being considered.

YEAR 2, QUARTER 1

$$\text{Annual Running TTHM Average, mg/}L = \frac{\text{Sum of Measurements, mg/}L}{\text{Number of Measurements}}$$

$$= \frac{0.09\text{ mg/}L + 0.08\text{ mg/}L + 0.12\text{ mg/}L + 0.09\text{ mg/}L}{4}$$

$$= \frac{0.38\text{ mg/}L}{4}$$

$$= 0.095\text{ mg/}L$$

YEAR 2, QUARTER 2

$$\text{Annual Running TTHM Average, mg/}L = \frac{0.11\text{ mg/}L + 0.09\text{ mg/}L + 0.08\text{ mg/}L + 0.12\text{ mg/}L}{4}$$

$$= \frac{0.40\text{ mg/}L}{4}$$

$$= 0.10\text{ mg/}L$$

YEAR 2, QUARTER 3

$$\text{Annual Running TTHM Average, mg/}L = \frac{0.13\text{ mg/}L + 0.11\text{ mg/}L + 0.09\text{ mg/}L + 0.08\text{ mg/}L}{4}$$

$$= \frac{0.41\text{ mg/}L}{4}$$

$$= 0.103\text{ mg/}L$$

YEAR 2, QUARTER 4

$$\text{Annual Running TTHM Average, mg/}L = \frac{0.07\text{ mg/}L + 0.13\text{ mg/}L + 0.11\text{ mg/}L + 0.09\text{ mg/}L}{4}$$

$$= \frac{0.40\text{ mg/}L}{4}$$

$$= 0.10\text{ mg/}L$$

EXAMPLE 14

A 450-mm diameter water main is to be flushed at a velocity of 1.2 m/sec. What should be the reading on the flow meter in liters per second?

Known		Unknown
Diameter, mm	= 450 mm	Flow, *L*/sec
	= 0.45 m	
Velocity, m/sec	= 1.2 m/sec	

1. Calculate the cross-sectional area of the pipe in square meters.

$$\text{Area, sq m} = (0.785)(\text{Diameter, m})^2$$

$$= (0.785)(0.45\text{ m})^2$$

$$= 0.159\text{ sq m}$$

2. Determine the flow in liters per second.

$$\text{Flow, }L\text{/sec} = (\text{Area, sq m})(\text{Velocity, m/sec})(1000\ L\text{/cu m})$$

$$= (0.159\text{ sq m})(1.2\text{ m/sec})(1000\ L\text{/cu m})$$

$$= 191\text{ liters/sec}$$

EXAMPLE 15

During a 20-minute time span the water in a tank one meter in diameter increases by 1.2 meters. Calculate the total flow in liters and the flow in liters per second.

Known		Unknown
Time, min	= 20 min	1. Volume, liters
Diameter, m	= 1 m	2. Flow, liters/sec
Depth, m	= 1.2 m	

1. Calculate the total flow in liters.

$$\text{Volume, liters} = (0.785)(\text{Diameter, m})^2(\text{Depth, m})(1000\ L\text{/cu m})$$

$$= (0.785)(1\text{ m})^2(1.2)(1000\ L\text{/cu m})$$

$$= 942\text{ liters}$$

2. Calculate the flow in liters per second.

$$\text{Flow, }L\text{/sec} = \frac{\text{Volume, liters}}{(\text{Time, min})(60\text{ sec/min})}$$

$$= \frac{942\text{ liters}}{(20\text{ min})(60\text{ sec/min})}$$

$$= 0.785\text{ liters/sec}$$

EXAMPLE 16

A water meter is tested in a laboratory. The meter reads 0.08 liters per second and the actual flow was 0.083 liters per second. Determine the meter accuracy as a percentage.

Known		Unknown
Meter Reading, *L*/sec	= 0.08 *L*/sec	Meter Accuracy, %
Actual Flow, *L*/sec	= 0.083 *L*/sec	

Determine the meter accuracy as a percentage.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, }L\text{/sec})(100\%)}{\text{Actual Flow, }L\text{/sec}}$$

$$= \frac{(0.08\ L\text{/sec})(100\%)}{0.083\ L\text{/sec}}$$

$$= 96.4\%$$

EXAMPLE 17

A water meter is tested in a laboratory. The meter reads 1550 liters. The actual flow was measured in a volumetric measuring tank one meter in diameter. During the meter test two meters of water were added to the tank. Determine the meter accuracy as a percentage.

Known		Unknown
Meter Reading, liters	= 1550 *L*	Meter Accuracy, %
Diameter, m	= 1 m	
Depth, m	= 2 m	

1. Calculate the actual volume of water which flowed through the meter in liters.

$$\text{Volume, liters} = (0.785)(\text{Diameter, m})^2(\text{Depth, m})(1000\ L\text{/cu m})$$

$$= (0.785)(1\text{ m})^2(2\text{ m})(1000\ L\text{/cu m})$$

$$= 1570\text{ liters}$$

2. Determine the meter accuracy as a percentage.

$$\text{Meter Accuracy, \%} = \frac{(\text{Meter Reading, }L)(100\%)}{\text{Actual Volume, }L}$$

$$= \frac{(1550\ L)(100\%)}{1570\ L}$$

$$= 98.7\%$$

EXAMPLE 18

A trench 1.5-meters wide, 320-meters long and 2-meters deep is to be excavated for a water main. How many cubic yards of soil have to be excavated for the water main?

Known		Unknown
Length, m	= 320 m	Volume Excavated, cu m
Width, m	= 1.5 m	
Depth, m	= 2 m	

Calculate the volume excavated in cubic meters.

$$\begin{aligned}\text{Volume, cu m} &= (\text{Length, m})(\text{Width, m})(\text{Depth, m})\\ &= (320\text{ m})(1.5\text{ m})(2\text{ m})\\ &= 960\text{ m}\end{aligned}$$

EXAMPLE 19

A flow meter indicates a flow rate of two liters per second. How many liters of water will flow through the meter in 45 minutes.

Known		Unknown
Flow Rate, *L*/sec	= 2 *L*/sec	Flow Volume, *L*
Time, min	= 45 min	

Calculate the total flow of water in liters.

$$\begin{aligned}\text{Flow Volume, } L &= (\text{Flow Rate, } L\text{/sec})(\text{Time, min})(60\text{ sec/min})\\ &= (2\ L\text{/sec})(45\text{ min})(60\text{ sec/min})\\ &= 5400\text{ liters}\end{aligned}$$

EXAMPLE 20

A chemical solution tank is 1.5 meters in diameter and two-meters deep. How long will it take to fill this tank when water flows at a rate of two liters per second?

Known		Unknown
Diameter, m	= 1.5 m	Time to Fill, min
Depth, m	= 2 m	
Flow Rate, *L*/sec	= 2 *L*/sec	

Calculate the volume in the tank in liters.

$$\begin{aligned}\text{Tank Volume, } L &= (0.785)(\text{Diameter, m})^2(\text{Depth, m})(100\ L\text{/cu m})\\ &= (0.785)(1.5\text{ m})^2(2\text{ m})(1000\ L\text{/cu m})\\ &= 3533\ L\end{aligned}$$

2. Calculate the time to fill the tank in minutes.

$$\begin{aligned}\text{Time to Fill, min} &= \frac{\text{Tank Volume, liters}}{(\text{Flow Rate, } L\text{/sec})(60\text{ sec/min})}\\ &= \frac{3533\ L}{(2\ L\text{/sec})(60\text{ sec/min})}\\ &= 29.4\text{ min}\end{aligned}$$

EXAMPLE 21

A cylindrical water storage tank is 10 meters in diameter and four meters high. Calculate the volume of water in cubic meters per meter of depth and then the total volume in cubic meters and megaliters (M*L*) when the water is 3.7 meters deep.

Known		Unknown
Diameter, m	= 10 m	1. Volume, cu m/m for a depth of 3.7 m
Height, m	= 4 m	2. Volume, cu m
Depth, m	= 3.7 m	3. Volume, M*L*

1. Calculate the volume of water in the tank per cubic meters of depth.

$$\text{Volume, cu m} = (\text{Area, sq m})(\text{Depth, m})$$

$$\begin{aligned}\text{Volume, cu m/m} &= (0.785)(\text{Diameter, m})^2(1\text{ m/1m})\\ &= (0.785)(10\text{ m})^2(1\text{ m/1m})\\ &= 78.5\text{ cu m/m}\end{aligned}$$

2. Calculate the volume of water in the tank in cubic-meters when the water is 3.7 meters deep in the tank.

$$\begin{aligned}\text{Volume, cu m} &= (\text{Volume, cu m/m})(\text{Depth, m})\\ &= (78.5\text{ cu m/m})(3.7\text{ m})\\ &= 290\text{ cu m}\end{aligned}$$

3. Convert the volume of water in the tank from cubic meters to mega or million liters (M*L*).

$$\begin{aligned}\text{Volume, M}L &= \frac{(\text{Volume, cu m})(1000\ L\text{/cu m})(1\text{ Million})}{1{,}000{,}000}\\ &= \frac{(290\text{ cu m})(1000\ L\text{/cu m})(1\text{ Million})}{1{,}000{,}000}\\ &= 0.29\text{ M}L\end{aligned}$$

EXAMPLE 22

Estimate the flow from a pipe in liters per second. Water is flowing from a 50-mm diameter pipe. The pipe is one meter above the point where the water hits the ground. The water hits the ground 2.3 meters (horizontal distance) from where the water leaves the pipe. See Figure A.3 on page 721 for a sketch of this problem.

Known		Unknown
Diameter, mm	= 50 mm	Flow, *L*/sec
Height, m	= 1 m	
Distance, m	= 2.3 m	

Estimate the flow from the pipe in liters per second.

$$\begin{aligned}\text{Flow, } L\text{/sec} &= \frac{1739(\text{Diameter, m})^2(\text{Distance, m})}{\sqrt{\text{Height, m}}}\\ &= \frac{1739(0.050\text{ m})^2(2.3\text{ m})}{\sqrt{1\text{ m}}}\\ &= 10.0\ L\text{/sec}\end{aligned}$$

A.154 Disinfection

EXAMPLE 23

How many liters of five percent sodium hypochlorite will be needed to disinfect a well with a 0.5-meter diameter casing and well screen? The well is 60 meters deep and there is 25 meters of water in the well. Use an initial chlorine dose of 100 mg/*L*.

Known		Unknown
Hypochlorite, %	= 5%	5% Hypochlorite, *L*
Chlorine Dose, mg/*L*	= 100 mg/*L*	
Diameter, m	= 0.5 m	
Well Depth, m	= 60 m	
Water Depth, m	= 25 m	

1. Calculate the volume of water in the well in liters.

$$\text{Water Vol, liters} = (0.785)(\text{Diameter, m})^2(\text{Depth, m})(1000\ L/\text{cu m})$$
$$= (0.785)(0.5\ \text{m})^2(25\ \text{m})(1000\ L/\text{cu m})$$
$$= 4906\ \text{liters}$$

2. Determine the grams of chlorine needed.

$$\text{Chlorine, gm} = \frac{(\text{Volume, } L)(\text{Dose, mg}/L)}{1000\ \text{mg/gm}}$$
$$= \frac{(4906\ L)(100\ \text{mg}/L)}{1000\ \text{mg/gm}}$$
$$= 491\ \text{gm}$$

3. Calculate the liters of five percent sodium hypochlorite solution needed. One liter of water weighs 1000 grams.

$$\text{Sodium Hypochlorite Solution, liters} = \frac{(\text{Chlorine, gm})(100\%)}{(1000\ \text{gm}/L)(\text{Hypochlorite, }\%)}$$
$$= \frac{(491\ \text{gm})(100\%)}{(1000\ \text{gm}/L)(5\%)}$$
$$= 9.8\ \text{liters}$$

Ten liters should do the job.

4. *ALTERNATE SOLUTION*

Calculate the liters of five percent sodium hypochlorite solution needed. A five percent solution is the same as 50,000 mg per liter.

$$\text{Sodium Hypochlorite Solution, liters} = \frac{(\text{Volume, } L)(\text{Dose, mg}/L)}{\text{Hypochlorite Solution, mg}/L}$$
$$= \frac{(4906\ L)(100\ \text{mg}/L)}{50{,}000\ \text{mg}/L}$$
$$= 9.8\ \text{liters}$$

EXAMPLE 24

A new 250-mm diameter water main 200-meters long needs to be disinfected. An initial chlorine dose of 400 mg/*L* is expected to maintain a chlorine residual of over 300 mg/*L* during the three-hour disinfection period. How many liters of 5.25 percent (52,500 mg/*L*) sodium hypochlorite solution will be needed?

Known	Unknown
Diameter of Pipe, m = 0.25 m	5.25% Hypochlorite, *L*
Length of Pipe, m = 200 m	
Chlorine Dose, mg/*L* = 400 mg/*L*	
Hypochlorite, % = 5.25%	
Hypochlorite, mg/*L* = 52,500 mg/*L*	

1. Calculate the volume of water in the pipe in liters.

$$\text{Pipe Vol, } L = (0.785)(\text{Diameter, m})^2(\text{Length, m})(1000\ L/\text{cu m})$$
$$= (0.785)(0.25\ \text{m})^2(200\ \text{m})(1000\ L/\text{cu m})$$
$$= 9813\ L$$

2. Calculate the liters of 5.25 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, } L = \frac{(\text{Volume, } L)(\text{Dose, mg}/L)}{\text{Hypochlorite Solution, mg}/L}$$
$$= \frac{(9813\ L)(400\ \text{mg}/L)}{52{,}500\ \text{mg}/L}$$
$$= 75\ \text{liters}$$

EXAMPLE 25

A service storage reservoir has been taken out of service for inspection, maintenance and repairs. The reservoir needs to be disinfected before being placed back on line. The reservoir is 12 meters in diameter and three-meters deep. An initial chlorine dose of 100 mg/*L* is expected to maintain a chlorine residual of over 50 mg/*L* during the 24-hour disinfection period. How many liters of 15 percent sodium hypochlorite solution will be needed?

Known	Unknown
Diameter, m = 12 m	15% Hypochlorite, *L*
Tank Depth, m = 3 m	
Chlorine Dose, mg/*L* = 100 mg/*L*	
Hypochlorite, % = 15%	
Hypochlorite, mg/*L* = 150,000 mg/*L*	

1. Calculate the volume of water in the tank in liters.

$$\text{Tank Volume, } L = (0.785)(\text{Diameter, m})^2(\text{Depth, m})(1000\ L/\text{cu m})$$
$$= (0.785)(12\ \text{m})^2(3\ \text{m})(1000\ L/\text{cu m})$$
$$= 339{,}120\ L$$

2. Calculate the liters of 15 percent sodium hypochlorite solution needed.

$$\text{Sodium Hypochlorite Solution, } L = \frac{(\text{Volume, } L)(\text{Dose, mg}/L)}{\text{Hypochlorite Solution, mg}/L}$$
$$= \frac{(339{,}120\ L)(100\ \text{mg}/L)}{150{,}000\ \text{mg}/L}$$
$$= 226\ \text{liters}$$

EXAMPLE 26

Calculate the actual chlorine dose in milligrams per liter if 800 liters of a two percent sodium hypochlorite solution were used to treat eight megaliters of water.

Known	Unknown
Volume, Hypocl, *L* = 800 *L*	Chlorine Dose, mg/*L*
Volume Water, M*L* = 8 M*L*	
Hypochlorite, % = 2%	
Hypochlorite, mg/*L* = 20,000 mg/*L*	

Calculate the actual chlorine dose in milligrams per liter.

$$\text{Actual Dose, mg}/L = \frac{(\text{Hypochlorite, mg}/L)(\text{Volume Hypocl, } L)(1\ \text{Million})}{(\text{Volume Water, M}L)(1{,}000{,}000)}$$
$$= \frac{(20{,}000\ \text{mg}/L)(800\ L)(1\ \text{Million})}{(8\ \text{M}L)(1{,}000{,}000)}$$
$$= 2.0\ \text{mg}/L$$

EXAMPLE 27

A deep-well turbine pump delivers 15 liters per second against typical operating heads. If the desired chlorine dose is 2.5 mg/*L*, what should be the chlorine feed rate in kilograms per day and milligrams per second.

Known	Unknown
Flow, *L*/sec = 15 *L*/sec	1. Chlorine Feed, kg/day
Dose, mg/*L* = 2.5 mg/*L*	2. Chlorine Feed, mg/sec

1. Calculate the chlorine feed in kilograms per day.

$$\text{Chlorine Feed, kg/day} = \frac{(\text{Flow, } L/\text{sec})(\text{Dose, mg}/L)(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{ hr/day})}{(1000 \text{ mg/gm})(1000 \text{ gm/kg})}$$

$$= \frac{(15\ L/\text{sec})(2.5 \text{ mg}/L)(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{ hr/day})}{(1000 \text{ mg/gm})(1000 \text{ gm/kg})}$$

$$= 3.24 \text{ kg/day}$$

2. Calculate the chlorine feed in milligrams per second.

$$\text{Chlorine Feed, mg/sec} = (\text{Flow, } L/\text{sec})(\text{Dose, mg}/L)$$

$$= (15\ L/\text{sec})(2.5 \text{ mg}/L)$$

$$= 37.5 \text{ mg/sec}$$

EXAMPLE 28

Estimate the chlorine demand for a water in milligrams per liter if the chlorine dose is 2.6 mg/*L* and the chlorine residual is 0.4 mg/*L*.

Known	Unknown
Chlorine, Dose, mg/*L* = 2.6 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual, mg/*L* = 0.4 mg/*L*	

Estimate the chlorine demand in milligrams per liter.

$$\text{Chlorine Demand, mg}/L = \text{Chlorine Dose, mg}/L - \text{Chlorine Residual, mg}/L$$

$$= 2.6 \text{ mg}/L - 0.4 \text{ mg}/L$$

$$= 2.2 \text{ mg}/L$$

EXAMPLE 29

Estimate the liters of hypochlorite pumped by a hypochlorinator if the hypochlorite solution is in a container with a diameter of one meter and the hypochlorite level drops 45 centimeters during a specific time period.

Known	Unknown
Diameter, m = 1 m	Hypochlorite Pumped, liters
Drop, cm = 45 cm	

Estimate the liters of hypochlorite pumped.

$$\text{Hypochlorite, liters} = (\text{Container Area, sq m})(\text{Drop, m})(1000\ L/\text{cu m})$$

$$= \frac{(0.785)(1 \text{ m})^2(45 \text{ cm})(1000\ L/\text{cu m})}{(100 \text{ cm/m})}$$

$$= 353 \text{ liters}$$

EXAMPLE 30

Estimate the desired strength (as a percent chlorine) of a hypochlorite solution which is pumped by a hypochlorinator that delivers 300 liters per day. The water being treated requires a chlorine dose of five kilograms of chlorine per day.

Known	Unknown
Hypochlorinator Flow, *L*/day = 300 *L*/day	Hypochlorite Strength, %
Chlorine Required, kg/day = 5 kg/day	

Estimate the desired hypochlorite strength as a percent chlorine.

$$\text{Hypochlorite Strength, \%} = \frac{(\text{Chlorine Required, kg/day})(100\%)}{(\text{Hypochlorinator Flow, } L/\text{day})(1 \text{ kg}/L)}$$

$$= \frac{(5 \text{ kg/day})(100\%)}{(300\ L/\text{day})(1 \text{ kg}/L)}$$

$$= 1.67\%$$

EXAMPLE 31

How many liters of water must be added to 40 liters of a five percent hypochlorite solution to produce a 1.67 percent hypochlorite solution:

Known	Unknown
Hypochlorite, *L* = 40 *L*	Water Added, *L*
Desired Hypo, % = 1.67%	
Actual Hypo, % = 5%	

Calculate the gallons of water that must be added to produce a 1.67 percent hypochlorite solution.

$$\text{Water Added, } L \text{ (to hypochlorite solution)} = \frac{(\text{Hypo, } L)(\text{Hypo, \%}) - (\text{Hypo, } L)(\text{Des Hypo, \%})}{\text{Desired Hypo, \%}}$$

$$= \frac{(40\ L)(5\%) - (40\ L)(1.67\%)}{1.67\%}$$

$$= \frac{200 - 66.8}{1.67}$$

$$= 80 \text{ liters}$$

WATER ABBREVIATIONS

ac	acre
ac-ft	acre-feet
af	acre feet
amp	ampere
°C	degrees Celsius
cfm	cubic feet per minute
cfs	cubic feet per second
Ci	Curie
cm	centimeter
cu ft	cubic feet
cu in	cubic inch
cu m	cubic meter
cu yd	cubic yard
°F	degrees Fahrenheit
ft	feet or foot
ft-lb/min	foot-pounds per minute
g	gravity
gal	gallon
gal/day	gallons per day
gm	gram
GPD	gallons per day
GPM	gallons per minute
gpg	grains per gallon
gr	grain
ha	hectare
HP	horsepower
hr	hour
in	inch
k	kilo
kg	kilogram
km	kilometer
kN	kilonewton
kW	kilowatt
kWh	kilowatt-hour
L	liter
lb	pound
lbs/sq in	pounds per square inch
m	meter
M	mega
M	million
mg	milligram
mg/*L*	milligram per liter
MGD	million gallons per day
m*L*	milliliter
min	minute
mm	millimeter
N	Newton
ohm	ohm
Pa	Pascal
pCi	picoCurie
psf	pounds per square foot
psi	pounds per square inch
psig	pounds per square inch gage
ppb	parts per billion
ppm	parts per million
sec	second
sq ft	square feet
sq in	square inches
W	watt

WATER WORDS

A Summary of the Words Defined

in

WATER TREATMENT PLAN OPERATION,
WATER DISTRIBUTION SYSTEM OPERATION
AND MAINTENANCE
and
SMALL WATER SYSTEM OPERATION AND MAINTENANCE

PROJECT PRONUNCIATION KEY

by Warren L. Prentice

The Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this Key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This Key is designed solely to aid operators in this program.

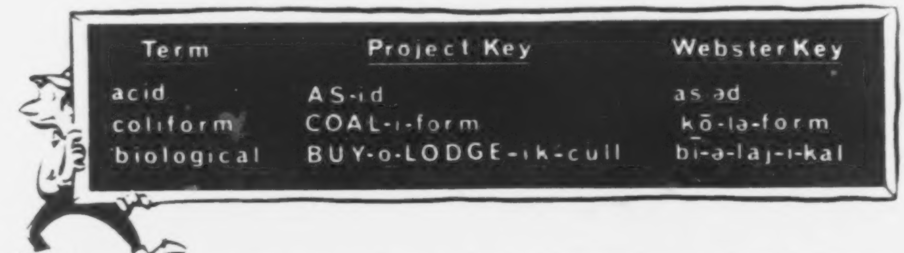
You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation Key. Each Key will be different from each other and from this Key. Examples of the differences between the Key used in this program and the *WEBSTER'S NEW WORLD DICTIONARY* "Key[1]", are shown below.

In using this Key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Project Key.

	SYLLABLE				
Word	1st	2nd	3rd	4th	5th
acid	AS	id			
coagulant	co	AGG	you	lent	
biological	BUY	o	LODGE	ik	cull

The first word *ACID* has its first syllable accented. The second word, *COAGULANT*, has its second syllable accented. The third word, *BIOLOGICAL*, has its first and third syllables accented.

We hope you will find the Key useful in unlocking the pronunciation of any new word.



Term	Project Key	Webster Key
acid	AS-id	as əd
coliform	COAL-i-form	kō-la-form
biological	BUY-o-LODGE-ik-cull	bī-ə-laj-i-kal

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[1] *The* WEBSTER'S NEW WORLD DICTIONARY, *Second College Edition, 1972, was chosen rather than an unabridged dictionary because of its availability to the operator. Other editions may be slightly different.*

WATER WORDS

ABC ABC

See **A**ssociation of **B**OARDS of **C**ertification

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACCURACY ACCURACY

How closely an instrument measures the true or actual value of the process variable being measured or sensed.

ACID RAIN ACID RAIN

Precipitation which has been rendered (made) acidic by airborne pollutants.

ACIDIC (uh-SID-ick) ACIDIC

The condition of water or soil which contains a sufficient amount of acid substances to lower the pH below 7.0.

ACIDIFIED (uh-SID-uh-FIE-d) ACIDIFIED

The addition of an acid (usually nitric or sulfuric) to a sample to lower the pH below 2.0. The purpose of acidification is to "fix" a sample so it won't change until it is analyzed.

ACRE-FOOT ACRE-FOOT

A volume of water that covers one acre to a depth of one foot, or 43,560 cubic feet (1233.5 cubic meters).

ACTIVATED CARBON ACTIVATED CARBON

Adsorptive particles or granules of carbon usually obtained by heating carbon (such as wood). These particles or granules have a high capacity to selectively remove certain trace and soluble materials from water.

ACUTE ACUTE

Effects of an exposure which causes severe symptoms to occur quickly.

ADSORBATE (add-SORE-bait) ADSORBATE

The material being removed by the adsorption process.

ADSORBENT (add-SORE-bent) ADSORBENT

The material (activated carbon) that is responsible for removing the undesirable substance in the adsorption process.

ADSORPTION (add-SORP-shun) ADSORPTION

The collection of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

AERATION (air-A-shun) AERATION

The process of adding air to water. Air can be added to water by either passing air through water or passing water through air.

AEROBIC (air-O-bick) AEROBIC

A condition in which "free" (atmospheric) or dissolved oxygen is present in the water.

AESTHETIC (es-THET-ick) AESTHETIC

Attractive or appealing.

AGE TANK AGE TANK

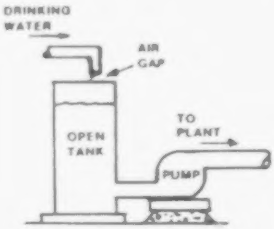
A tank used to store a chemical solution of known concentration for feed to a chemical feeder. Also called a DAY TANK.

AIR BINDING AIR BINDING

A situation where air enters the filter media. Air is harmful to both the filtration and backwash processes. Air can prevent the passage of water during the filtration process and can cause the loss of filter media during the backwash process.

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, that separates a drinking (potable) water supply to be protected from another water system in a water treatment plant or other location. This open gap prevents the contamination of drinking water by backsiphonage or backflow because there is no way raw water or any other water can reach the drinking water.



AIR PADDING AIR PADDING

Pumping dry air into a container to assist with the withdrawal of a liquid or to force a liquefied gas such as chlorine out of a container.

AIR STRIPPING AIR STRIPPING

A treatment process used to remove dissolved gases and volatile substances from water. Large volumes of air are bubbled through the water being treated to remove (strip out) the dissolved gases and volatile substances.

ALARM CONTACT ALARM CONTACT

A switch that operates when some pre-set low, high or abnormal condition exists.

ALGAE (Al-gee) ALGAE

Microscopic plants which contain chlorophyll and live floating or suspended in water. They also may be attached to structures, rocks or other submerged surfaces. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. Their biological activities appreciably affect the pH and dissolved oxygen of the water.

ALGAL BLOOM (AL-gull) ALGAL BLOOM

Sudden, massive growths of microscopic and macroscopic plant life, such as green or blue-green algae, which develop in lakes and reservoirs.

ALGICIDE (AL-gi-SIDE) ALGICIDE

Any substance or chemical specifically formulated to kill or control algae.

ALIPHATIC HYDROXY ACIDS (AL-uh-FAT-ick) ALIPHATIC HYDROXY ACIDS

Organic acids with carbon atoms arranged in branched or unbranched open chains rather than in rings.

ALIQUOT (AL-li-kwot) ALIQUOT

Portion of a sample.

ALKALI (AL-ka-lie) ALKALI

Various soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids to form neutral salts and may be used in chemical water treatment processes.

ALKALINE (AL-ka-LINE) ALKALINE

The condition of water or soil which contains a sufficient amount of alkali substances to raise the pH above 7.0.

ALKALINITY (AL-ka-LIN-it-tee) ALKALINITY

The capacity of water to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

ALLUVIAL (uh-LOU-vee-ul) ALLUVIAL

Relating to mud and/or sand deposited by flowing water. Alluvial deposits may occur after a heavy rain storm.

ALTERNATING CURRENT (A.C.) ALTERNATING CURRENT (A.C.)

An electric current that reverses its direction (positive/negative values) at regular intervals.

ALTITUDE VALVE ALTITUDE VALVE

A valve that automatically shuts off the flow into an elevated tank when the water level in the tank reaches a predetermined level. The valve automatically opens when the pressure in the distribution system drops below the pressure in the tank.

AMBIENT TEMPERATURE (AM-bee-ent) AMBIENT TEMPERATURE

Temperature of the surrounding air (or other medium). For example, temperature of the room where a gas chlorinator is installed.

AMERICAN WATER WORKS ASSOCIATION AMERICAN WATER WORKS ASSOCIATION

A professional organization for all persons working in the water utility field. For information on AWWA membership and publications, contact AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235.

AMPERAGE (AM-purr-age) AMPERAGE

The strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.

AMPERE (AM-peer) AMPERE

The unit used to measure current strength. The current produced by an electromotive force of one volt acting through a resistance of one ohm.

AMPEROMETRIC (am-PURR-o-MET-rick) AMPEROMETRIC

Based on the electric current that flows between two electrodes in a solution.

AMPEROMETRIC TITRATION AMPEROMETRIC TITRATION

A means of measuring concentrations of certain substances in water (such as strong oxidizers) based on the electric current that flows during a chemical reaction. See TITRATE.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" (atmospheric) or dissolved oxygen is *NOT* present in water.

ANALOG ANALOG

The readout of an instrument by a pointer (or other indicating means) against a dial or scale.

ANALYZER ANALYZER

A device which conducts periodic or continuous measurement of some factor such as chlorine, fluoride or turbidity. Analyzers operate by any of several methods including photocells, conductivity or complex instrumentation.

ANION (AN-EYE-en) ANION

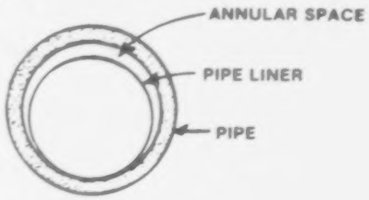
A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of a difference in electrical potential. Chloride (Cl^-) is an anion.

ANIONIC POLYMER (AN-eye-ON-ick) ANIONIC POLYMER

A polymer having negatively charged groups of ions; often used as a filter aid and for dewatering sludges.

ANNULAR SPACE (AN-you-ler) ANNULAR SPACE

A ring-shaped space located between two circular objects, such as two pipes.



ANODE (an-O-d) ANODE

The positive pole or electrode of an electrolytic system, such as a battery. The anode attracts negatively charged particles or ions (anions).

APPROPRIATIVE APPROPRIATIVE

Water rights to or ownership of a water supply which is acquired for the beneficial use of water by following a specific legal procedure.

APPURTENANCE (uh-PURR-ten-nans) APPURTENANCE

Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

AQUEOUS (A-kwee-us) AQUEOUS

Something made up of, similar to, or containing water; watery.

AQUIFER (ACK-wi-fer) AQUIFER

A natural underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water.

ARTESIAN (are-TEE-zhun) ARTESIAN

Pertaining to groundwater, a well, or underground basin where the water is under a pressure greater than atmospheric and will rise above the level of its upper confining surface if given an opportunity to do so.

ASEPTIC (a-SEP-tick) ASEPTIC

Free from the living germs of disease, fermentation or putrefaction. Sterile.

ASSOCIATION OF BOARDS OF CERTIFICATION ASSOCIATION OF BOARDS OF CERTIFICATION

An international organization representing over seventy boards which certify the operators of waterworks and wastewater facilities. For information on ABC publications regarding the preparation of and how to study for operator certification examinations, contact ABC, P.O. Box 2266, Ames, Iowa 50010.

ASYMMETRIC (A-see-MET-rick) ASYMMETRIC

Not similar in size, shape, form or arrangement of parts on opposite sides of a line, point or plane.

ATOM ATOM

The smallest unit of a chemical element; composed of protons, neutrons and electrons.

AUDIT, WATER AUDIT, WATER

A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

AVAILABLE CHLORINE AVAILABLE CHLORINE

A measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine when compared with that of elemental (liquid or gaseous) chlorine.

AVAILABLE EXPANSION AVAILABLE EXPANSION

The vertical distance from the sand surface to the underside of a trough in a sand filter. This distance is also called FREEBOARD.

AVERAGE AVERAGE

A number obtained by adding quantities or measurements and dividing the sum or total by the number of quantities or measurements. Also called the ARITHMETIC MEAN.

$$\text{Average} = \frac{\text{Sum of Measurements}}{\text{Number of Measurements}}$$

AVERAGE DEMAND AVERAGE DEMAND

The total demand for water during a period of time divided by the number of days in that time period. This is also called the AVERAGE DAILY DEMAND.

AWWA AWWA

See AMERICAN WATER WORKS ASSOCIATION.

AXIAL TO IMPELLER AXIAL TO IMPELLER

The direction in which material being pumped flows around the impeller or flow parallel to the impeller shaft.

AXIS OF IMPELLER AXIS OF IMPELLER

An imaginary line running along the center of a shaft (such as an impeller shaft).

BACK PRESSURE BACK PRESSURE

A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

BACKFLOW BACKFLOW

A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than an intended source. Also see BACKSIPHONAGE.

BACKSIPHONAGE BACKSIPHONAGE

A form of backflow caused by a negative or below atmospheric pressure within a water system. Also see BACKFLOW.

BACKWASHING BACKWASHING

The process of reversing the flow of water back through the filter media to remove the entrapped solids.

BACTERIA (back-TEER-e-uh) BACTERIA

Bacteria are living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BAFFLE BAFFLE

A flat board or plate, deflector, guide or similar device constructed or placed in flowing water or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids (water, chemical solutions, slurry).

BAILER (BAY-ler) BAILER

A 10- to 20-foot-long pipe equipped with a valve at the lower end. A bailer is used to remove slurry from the bottom or the side of a well as it is being drilled.

BASE METAL BASE METAL

A metal (such as iron) which reacts with dilute hydrochloric acid to form hydrogen. Also see NOBLE METAL.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated or a chemical solution is prepared, and the tank is emptied. The tank may then be filled and the process repeated.

BIOCHEMICAL OXYGEN DEMAND BIOCHEMICAL OXYGEN DEMAND

BOD. The rate at which microorganisms use the oxygen in water while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIOLOGICAL GROWTH BIOLOGICAL GROWTH

The activity and growth of any and all living organisms.

BLANK BLANK

A bottle containing only dilution water or distilled water; the sample being tested is not added. Tests are frequently run on a SAMPLE and a BLANK and the differences are compared.

BOD (pronounce as separate letters) BOD

Biochemical **O**xygen **D**emand. The rate at which microorganisms use the oxygen in water while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BONNET (BON-it) BONNET

The cover on a gate valve.

BOWLS, PUMP BOWLS, PUMP

The submerged pumping unit in a well, including the shaft, impellers and housing.

BRAKE HORSEPOWER BRAKE HORSEPOWER

(1) The horsepower required at the top or end of a pump shaft (input to a pump).

(2) The energy provided by a motor or other power source.

BREAKPOINT CHLORINATION BREAKPOINT CHLORINATION

Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

BREAKTHROUGH BREAKTHROUGH

A crack or break in a filter bed allowing the passage of floc or particulate matter through a filter. This will cause an increase in filter effluent turbidity. A breakthrough can occur (1) when a filter is first placed in service, (2) when the effluent valve suddenly opens or closes, and (3) during periods of excessive head loss through the filter (including when the filter is exposed to negative heads).

BRINELLING (bruh-NEL-ing) BRINELLING

Tiny indentations (dents) high on the shoulder of the bearing race or bearing. A type of bearing failure.

BUFFER BUFFER

A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BUFFER CAPACITY BUFFER CAPACITY

A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water for offering a resistance to changes in pH.

C FACTOR C FACTOR

A factor or value used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between two pressure gages, and the friction or energy loss of the water between the gages.

$$\text{C Factor} = \frac{\text{Flow, GPM}}{193.75\ (\text{Diameter, ft})^{2.63}\ (\text{Slope})^{0.54}}$$

CAISSON (KAY-sawn) CAISSON

A structure or chamber which is usually sunk or lowered by digging from the inside. Used to gain access to the bottom of a stream or other body of water.

CALCIUM CARBONATE ($CaCO_3$) EQUIVALENT CALCIUM CARBONATE ($CaCO_3$) EQUIVALENT

An expression of the concentration of specified constituents in water in terms of their equivalent value to calcium carbonate. For example, the hardness in water which is caused by calcium, magnesium and other ions is usually described as calcium carbonate equivalent.

CALIBRATION CALIBRATION

A procedure which checks or adjusts an instrument's accuracy by comparison with a standard or reference.

CAPILLARY ACTION CAPILLARY ACTION

The movement of water through very small spaces due to molecular forces.

CAPILLARY FORCES CAPILLARY FORCES

The molecular forces which cause the movement of water through very small spaces.

CAPILLARY FRINGE CAPILLARY FRINGE

The porous material just above the water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void spaces.

CARCINOGEN (car-SIN-o-jen) CARCINOGEN

Any substance which tends to produce cancer in an organism.

CATALYST (CAT-uh-LIST) CATALYST

A substance that changes the speed or yield of a chemical reaction without being consumed or chemically changed by the chemical reaction.

CATALYZE (CAT-uh-LIZE) CATALYZE

To act as a catalyst. Or, to speed up a chemical reaction.

CATALYZED (CAT-uh-LIZED) CATALYZED

To be acted upon by a catalyst.

CATHODE (KA-thow-d) CATHODE

The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations).

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. A low-voltage current is made to flow through a liquid (water) or a soil in contact with the metal in such a manner that the external electromotive force renders the metal structure cathodic. This concentrates corrosion on auxiliary anodic parts which are deliberately allowed to corrode instead of letting the structure corrode.

CATION (CAT-EYE-en) CATION

A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in electrical potential. Sodium ion (Na^+) is a cation.

CATIONIC POLYMER CATIONIC POLYMER

A polymer having positively charged groups of ions; often used as a coagulant aid.

CAVITATION (CAV-uh-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.

CENTRATE CENTRATE

The water leaving a centifuge after most of the solids have been removed.

CENTRIFUGAL PUMP (sen-TRIF-uh-gull) CENTRIFUGAL PUMP

A pump consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection. As the rotating impeller whirls the water around, centrifugal force builds up enough pressure to force the water through the discharge outlet.

CENTRIFUGE CENTRIFUGE

A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.

CHECK VALVE CHECK VALVE

A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flow.

CHELATION (key-LAY-shun) CHELATION

A chemical complexing (forming or joining together) of metallic cations (such as copper) with certain organic compounds, such as EDTA (ethylene diamine tetracetic acid). Chelation is used to prevent the precipitation of metals (copper). Also see SEQUESTRATION.

CHLORAMINES (KLOR-uh-means) CHLORAMINES

Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.

CHLORINATION (KLOR-uh-NAY-shun) CHLORINATION

The application of chlorine to water, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results (aiding coagulation and controlling tastes and odors).

CHLORINATOR (KLOR-uh-NAY-ter) CHLORINATOR

A metering device which is used to add chlorine to water.

CHLORINE DEMAND CHLORINE DEMAND

Chlorine demand is the difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

$$\text{Chlorine Demand, mg}/L = \underset{\text{Applied, mg}/L}{\text{Chlorine}} - \underset{\text{Residual, mg}/L}{\text{Chlorine}}$$

CHLORINE REQUIREMENT CHLORINE REQUIREMENT

The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or oxidizing some substance in the water. In each case a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CHLOROPHENOLIC (klor-o-FEE-NO-lick) CHLOROPHENOLIC

Chlorophenolic compounds are phenolic compounds (carbolic acid) combined with chlorine.

CHLOROPHENOXY (KLOR-o-fuh-KNOX-ee) CHLOROPHENOXY

A class of herbicides that may be found in domestic water supplies and cause adverse health effects. Two widely used chlorophenoxy herbicides are 2,4-D (2,4-Dichlorophenoxy acetic acid) and 2,4,5-TP (2,4,5-Trichlorophenoxy propionic acid (silvex)).

CHLORORGANIC (klor-or-GAN-nick) CHLORORGANIC

Organic compounds combined with chlorine. These compounds generally originate from, or are associated with, life processes such as those of algae in water.

CHRONIC CHRONIC

Effects of an exposure which causes symptoms to continue for a long time.

CIRCLE OF INFLUENCE CIRCLE OF INFLUENCE

The circular outer edge of a depression produced in the water table by the pumping of water from a well. Also see CONE OF INFLUENCE and CONE OF DEPRESSION.

[SEE DRAWING ON PAGE 450]

CIRCUIT CIRCUIT

The complete path of an electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

CIRCUIT BREAKER CIRCUIT BREAKER

A safety device in an electrical circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.

CISTERN (SIS-turn) CISTERN

A small tank (usually covered) or a storage facility used to store water for a home or farm. Often used to store rain water.

CLARIFIER (KLAIR-uh-fire) CLARIFIER

A large circular or rectangular tank or basin in which water is held for a period of time, during which the heavier suspended solids settle to the bottom. Clarifiers are also called SETTLING BASINS and SEDIMENTATION BASINS.

CLASS, PIPE AND FITTINGS CLASS, PIPE AND FITTINGS

The working pressure rating of a specific pipe for use in water distribution systems which includes allowances for surges. The term is used fro cast iron, ductile iron, asbestos cement and some plastic pipe.

CLEAR WELL CLEAR WELL

A reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand. Also used to provide chlorine contact time for disinfection.

COAGULANT AID COAGULANT AID

Any chemical or substance used to assist or modify coagulation.

COAGULANTS (co-AGG-you-lents) COAGULANTS

Chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the water by settling, skimming, draining or filtering.

COAGULATION (co-AGG-you-LAY-shun) COAGULATION

The clumping together of very fine particles into larger particles caused by the use of chemicals (coagulants). The chemicals neutralize the electrical charges of the fine particles and cause destabilization of the particles. This clumping together makes it easier to separate the solids from the water by settling, skimming, draining, or filtering.

COLIFORM (COAL-i-form) COLIFORM

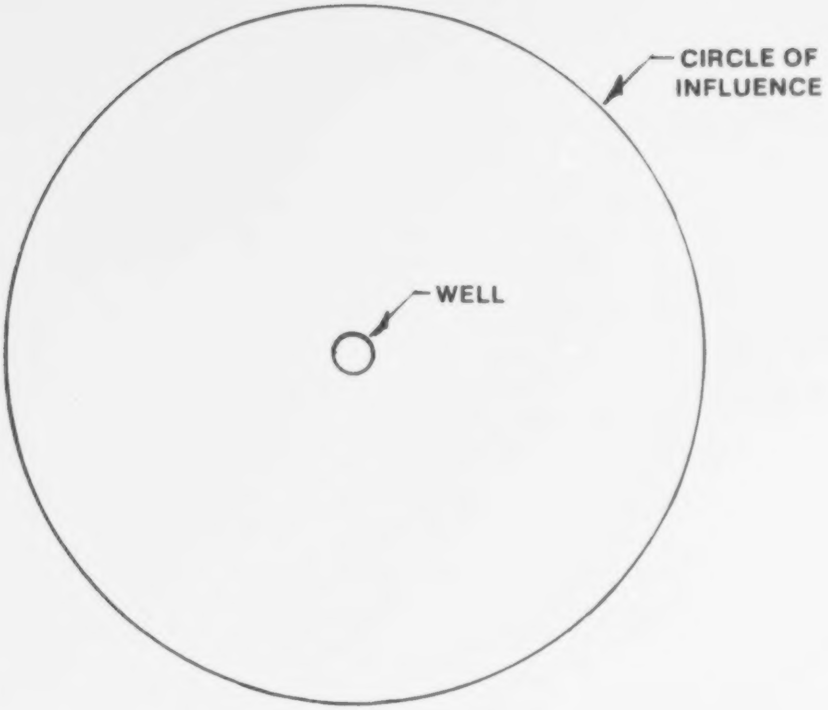
A group of bacteria found in the intestines of warm-blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhibit the intestines of warm-blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.

COLLOIDS (CALL-loids) COLLOIDS

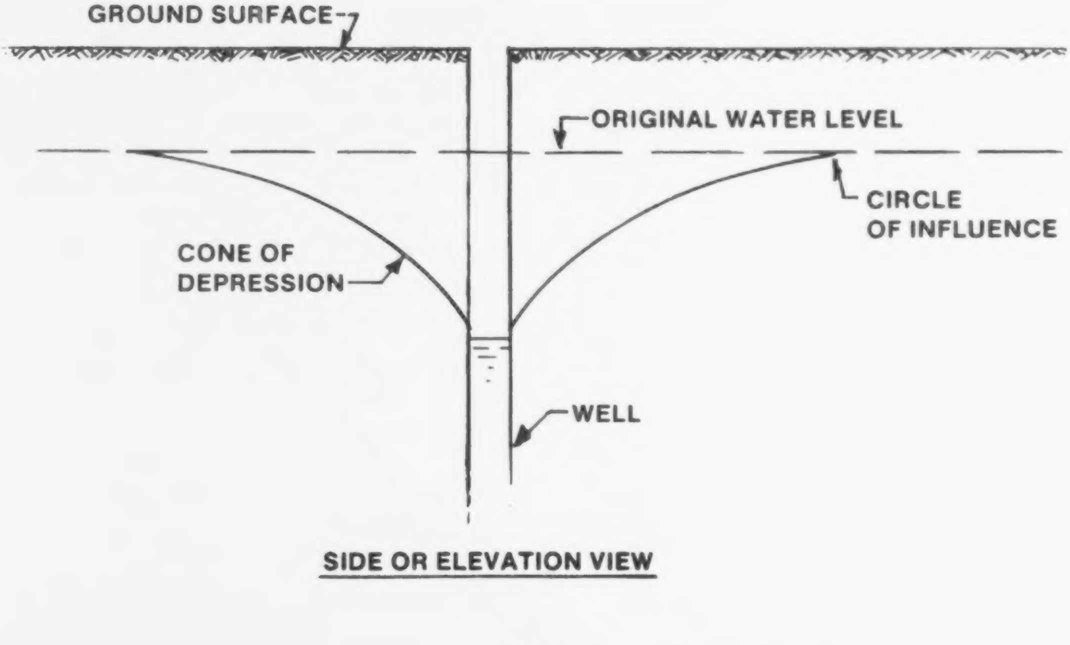
Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge. When most of the particles in water have a negative electrical charge, they tend to repel each other. This repulsion prevents the particles from clumping together, becoming heavier, and settling out.

COLORIMETRIC MEASUREMENT COLORIMETRIC MEASUREMENT

A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity. The specific color of the sample, developed by addition of chemical reagents, is measured with a photoelectric colorimeter or is compared with "color standards" using, or corresponding with, known concentrations of the chemical.


CIRCLE OF INFLUENCE
WELL

TOP OR PLAN VIEW


GROUND SURFACE
ORIGINAL WATER LEVEL
CIRCLE OF INFLUENCE
CONE OF DEPRESSION
WELL

SIDE OR ELEVATION VIEW

COMBINED AVAILABLE RESIDUAL CHLORINE COMBINED AVAILABLE RESIDUAL CHLORINE

The concentration of residual chlorine which is combined with ammonia (NH_3) and/or organic nitrogen in water as a chloramine (or other chloro derivative) yet is still available to oxidize organic matter and utilize its bactericidal properties.

COMBINED RESIDUAL CHLORINATION COMBINED RESIDUAL CHLORINATION

The application of chlorine to water to produce combined available residual chlorine. This residual can be made up of monochloramines, dichloramines, and nitrogen trichloride

COMPLETE TREATMENT COMPLETE TREATMENT

A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation and filtration. Also called CONVENTIONAL FILTRATION

COMPOSITE (come-PAH-zit) (PROPORTIONAL) SAMPLES COMPOSITE (PROPORTIONAL) SAMPLES

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the rate of flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

COMPOUND COMPOUND

A substance composed of two or more elements whose composition is constant. For example, table salt (sodium chloride-NaCl) is a compound.

CONCENTRATION POLARIZATION CONCENTRATION POLARIZATION

(1) The ratio of the salt concentration in the membrane boundary layer to the salt concentration in the bulk stream. The most common and serious problem resulting from concentration polarization is the increasing tendency for precipitation of sparingly soluble salts and the deposition of particulate matter on the membrane surface.

(2) Used in corrosion studies to indicate a depletion of ions near an electrode.

(3) The basis for chemical analysis by a polarograph.

CONDUCTANCE CONDUCTANCE

A rapid method of estimating the dissolved-solids content of a water supply. The measurement indicates the capacity of a sample of water to carry an electrical current, which is related to the concentration of ionized substances in the water. Also called SPECIFIC CONDUCTANCE.

CONDUCTIVITY CONDUCTIVITY

A measure of the ability of a solution (water) to carry an electric current.

CONDUCTOR CONDUCTOR

A substance, body, device or wire that readily conducts or carries electrical current.

CONDUCTOR CASING CONDUCTOR CASING

The outer casing of a well. The purpose of this casing is to prevent contaminants from surface waters or shallow groundwaters from entering a well.

CONE OF DEPRESSION CONE OF DEPRESSION

The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. Also see CIRCLE OF INFLUENCE and CONE OF INFLUENCE.

[SEE DRAWING ON PAGE 450]

CONE OF INFLUENCE CONE OF INFLUENCE

The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. Also see CIRCLE OF INFLUENCE and CONE OF DEPRESSION.

[SEE DRAWING ON PAGE 450]

CONFINED SPACE* CONFINED SPACE

A space defined by the concurrent existence of the following conditions:

A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and

B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

Also see definitions of *DANGEROUS AIR CONTAMINATION* and *DEFICIENCY*.

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* *CONFINED SPACES, General Industry Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service, Sacramento, California, October, 1980.*

CONSOLIDATED FORMATION CONSOLIDATED FORMATION

A geologic material whose particles are stratified (layered), cemented or firmly packed together (hard rock); usually occurring at a depth below the ground surface. Also see UNCONSOLIDATED FORMATION.

CONTACTOR CONTACTOR

An electrical switch, usually magnetically operated.

CONTAMINATION CONTAMINATION

The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use.

CONTINUOUS SAMPLE CONTINUOUS SAMPLE

A flow of water from a particular place in a plant to the location where samples are collected for testing. This continuous stream may be used to obtain grab or composite samples. Frequently, several taps (faucets) will flow continuously in the laboratory to provide test samples from various places in a water treatment plant.

CONTROL LOOP CONTROL LOOP

The path through the control system between the sensor, which measures a process variable, and the controller, which controls or adjusts the process variable.

CONTROL SYSTEM CONTROL SYSTEM

A system which senses and controls its own operation on a close, continuous basis in what is called proportional (or modulating) control.

CONTROLLER CONTROLLER

A device which controls the starting, stopping, or operation of a device or piece of equipment.

CONVENTIONAL FILTRATION CONVENTIONAL FILTRATION

A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation and filtration. Also called COMPLETE TREATMENT. Also see DIRECT FILTRATION and IN-LINE FILTRATION.

CONVENTIONAL TREATMENT CONVENTIONAL TREATMENT

See CONVENTIONAL FILTRATION. Also called COMPLETE TREATMENT.

CORPORATION STOP CORPORATION STOP

A water service shutoff valve located at a street water main. This valve cannot be operated from the ground surface because it is buried and there is no valve box. Also called a CORPORATION COCK.

CORROSION CORROSION

The gradual decomposition or destruction of a material by chemical action, often due to an electrochemical reaction. Corrosion may be caused by (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, or (3) differential-concentration cells. Corrosion starts at the surface of a material and moves inward.

CORROSION INHIBITORS CORROSION INHIBITORS

Substances that slow the rate of corrosion.

CORROSIVITY CORROSIVITY

An indication of the corrosiveness of a water. The corrosiveness of a water is described by the water's pH, alkalinity, hardness, temperature, total dissolved solids, dissolved oxygen concentration, and the Langelier Index.

COULOMB (COO-lahm) COULOMB

A measurement of the amount of electrical charge conveyed by an electric current of one ampere in one second. One coulomb equals about 6.25×10^{18} electrons (6,250,000,000,000,000,000 electrons).

COUPON COUPON

A steel specimen inserted into water to measure the corrosiveness of water. The rate of corrosion is measured as the loss of weight of the coupon (in milligrams) per surface area (in square decimeters) exposed to the water per day.

10 decimeters = 1 meter = 100 centimeters

CROSS-CONNECTION CROSS-CONNECTION

A connection between a drinking (potable) water system and an unapproved water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross-connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

CURB STOP CURB STOP

A water service shutoff valve located in a water service pipe near the curb and between the water main and the building. This valve is usually operated by a wrench or valve key and is used to start or stop flows in the water service line to a building. Also called a "curb cock."

CURIE CURIE

A measure of radioactivity. One Curie of radioactivity is equivalent to 3.7 × 10^{10} or 37,000,000,000 nuclear disintegrations per second.

CURRENT CURRENT

A movement or flow of electricity. Water flowing in a pipe is measured in gallons per second past a certain point, not by the number of water molecules going past a point. Electric current is measured by the number of coulombs per second flowing past a certain point in a conductor. A coulomb is equal to about 6.25 × 10^{18} electrons (6,250,000,000,000,000,000 electrons). A flow of one coulomb per second is called one ampere, the unit of the rate of flow of current.

DANGEROUS AIR CONTAMINATION DANGEROUS AIR CONTAMINATION

An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/or explosive, toxic or otherwise injurious or incapacitating substances.

A. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit.

B. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the minimum explosive concentration of the particulate.

C. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.

DATEOMETER (day-TOM-uh-ter) DATEOMETER

A small calendar disc attached to motors and equipment to indicate the year in which the last maintenance service was performed.

DATUM LINE DATUM LINE

A line from which heights and depths are calculated or measured. Also called a DATUM PLANE or a DATUM LEVEL.

DAY TANK DAY TANK

A tank used to store a chemical solution of known concentration for feed to a chemical feeder. A day tank usually stores sufficient chemical solution to properly treat the water being treated for at least one day. Also called an AGE TANK.

DEAD END DEAD END

The end of a water main which is not connected to other parts of the distribution system by means of a connecting loop of pipe.

DECANT DECANT

To draw off the upper layer of liquid (water) after the heavier material (a solid or another liquid) has settled.

DECHLORINATION (dee-KLOR-uh-NAY-shun) DECHLORINATION

The deliberate removal of chlorine from water. The partial or complete reduction of residual chlorine by any chemical or physical process.

DECIBEL (DES-uh-bull) DECIBEL

A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average level at which sound causes pain to humans.

DECOMPOSITION DECOMPOSITION

The conversion of chemically unstable materials to more stable forms by chemical or biological action. If organic matter decays when there is no oxygen present (anaerobic conditions or putrefaction), undesirable tastes and odors are produced. Decay of organic matter when oxygen is present (aerobic conditions) tends to produce much less objectionable tastes and odors.

DEFLUORIDATION (de-FLOOR-uh-DAY-shun) DEFLUORIDATION

The removal of excess fluoride in drinking water to prevent the mottling (brown stains) of teeth.

DEGASIFICATION (DEE-GAS-if-uh-KAY-shun) DEGASIFICATION

A water treatment process which removes dissolved gases from the water. The gases may be removed by either mechanical or chemical treatment methods or a combination of both.

DEMINERALIZATION (DEE-MIN-er-al-uh-ZAY-shun) DEMINERALIZATION

A treatment process which removes dissolved minerals (salts) from water.

DENSITY (DEN-sit-tee) DENSITY

A measure of how heavy a substance (solid, liquid or gas) is for its size. Density is expressed in terms of weight per unit volume, that is, grams per cubic centimeter or pounds per cubic feet. The density of water (at 4°C or 39°F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.

DESALINIZATION (DEE-SAY-leen-uh-ZAY-shun) DESALINIZATION

The removal of dissolved salts (such as sodium chloride, NaCl) from water by natural means (leaching) or by specific water treatment processes.

DESICCANT (DESS-uh-kant) DESICCANT

A drying agent which is capable of removing or absorbing moisture from the atmosphere in a small enclosure.

DESICCATION (DESS-uh-KAY-shun) DESICCATION

A process used to thoroughly dry air; to remove virtually all moisture from air.

DESICCATOR (DESS-uh-KAY-tor) DESICCATOR

A closed container into which heated weighing or drying dishes are placed to cool in a dry environment. The dishes may be empty or they may contain a sample. Desiccators contain a substance, such as anhydrous calcium chloride, which absorbs moisture and keeps the relative humidity near zero so that the dish or sample will not gain weight from absorbed moisture.

DESTRATIFICATION (de-STRAT-uh-fuh-KAY-shun) DESTRATIFICATION

The development of vertical mixing within a lake or reservoir to eliminate (either totally or partially) separate layers of temperature, plant, or animal life. This vertical mixing can be caused by mechanical means (pumps) or through the use of forced air diffusers which release air into the lower layers of the reservoir.

DETECTION LAG DETECTION LAG

The time period between the moment a change is made and the moment when such a change is finally sensed by the associated measuring instrument.

DETENTION TIME DETENTION TIME

(1) The theoretical (calculated) time required for a small amount of water to pass through a tank at a given rate of flow.

(2) The actual time in hours, minutes or seconds that a small amount of water is in a settling basin, flocculating basin or rapid-mix chamber. In storage reservoirs, detention time is the length of time entering water will be held before being drafted for use (several weeks to years, several months being typical).

$$\text{Detention Time, hr} = \frac{(\text{Basin Volume, gal})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

DEW POINT DEW POINT

The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air.

DEWATER DEWATER

(1) To remove or separate a portion of the water present in a sludge or slurry. To dry sludge so it can be handled and disposed of.

(2) To remove or drain the water from a tank or a trench.

DIATOMACEOUS EARTH (DYE-uh-toe-MAY-shus) DIATOMACEOUS EARTH

A fine, siliceous (made of silica) "earth" composed mainly of the skeletal remains of diatoms.

DIATOMS (DYE-uh-toms) DIATOMS

Unicellular (single cell), microscopic algae with a rigid (box-like) internal structure consisting mainly of silica.

DIGITAL READOUT DIGITAL READOUT

Use of numbers to indicate the value or measurement of a variable. The readout of an instrument by a direct, numerical reading of the measured value.

DILUTE SOLUTION DILUTE SOLUTION

A solution that has been made weaker usually by the addition of water.

DIMICTIC (die-MICK-tick) DIMICTIC

Lakes and reservoirs which freeze over and normally go through two stratification and two mixing cycles within a year.

DIRECT CURRENT (D.C.) DIRECT CURRENT (D.C.)

Electrical current flowing in one direction only and essentially free from pulsation.

DIRECT FILTRATION DIRECT FILTRATION

A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation, minimal flocculation, and filtration. The flocculation facilities may be omitted, but the physical-chemical reactions will occur to some extent. The sedimentation process is omitted. Also see CONVENTIONAL FILTRATION and IN-LINE FILTRATION.

DIRECT RUNOFF DIRECT RUNOFF

Water that flows over the ground surface or through the ground directly into streams, rivers, or lakes.

DISCHARGE HEAD DISCHARGE HEAD

The pressure (in pounds per square inch or psi) measured at the centerline of a pump discharge and very close to the discharge flange, converted into feet.

Discharge Head, ft = (Discharge Pressure, psi)(2.31 ft/psi)

DISINFECTION (dis-in-FECK-shun) DISINFECTION

The process designed to kill most microorganisms in water, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water treatment. Compare with STERILIZATION.

DISTILLATE (DIS-tuh-late) DISTILLATE

In the distillation of a sample, a portion is evaporated; the part that is condensed afterwards is the distillate.

DIVALENT (die-VAY-lent) DIVALENT

Having a valence of two, such as the ferrous ion, Fe^{2+}.

DIVERSION DIVERSION

Use of part of a stream flow as a water supply.

DPD (pronounce as separate letters) DPD

A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. DPD stands for N,N-diethyl-p-phenylene-diamine.

DRAFT DRAFT

(1) The act of drawing or removing water from a tank or reservoir.
(2) The water which is drawn or removed from a tank or reservoir.

DRAWDOWN DRAWDOWN

(1) The drop in the water table or level of water in the ground when water is being pumped from a well.
(2) The amount of water used from a tank or reservoir.
(3) The drop in the water level of a tank or reservoir.

DYNAMIC PRESSURE DYNAMIC PRESSURE

When a pump is operating, the vertical distance (in feet) from a reference point (such as a pump centerline) to the hydraulic grade line is the dynamic head.

Dynamic Pressure, psi = (Dynamic Head, ft) (0.433 psi/ft)

EDUCTOR (e-DUCK-ter) EDUCTOR

A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump. As an injector, it is used to produce vacuum for chlorinators.

EFFECTIVE RANGE EFFECTIVE RANGE

That portion of the design range (usually upper 90 percent) in which an instrument has acceptable accuracy. Also see RANGE and SPAN.

EFFECTIVE SIZE (E.S.) EFFECTIVE SIZE (E.S.)

The diameter of the particles in a granular sample (filter media) for which 10 percent of the total grains are smaller and 90 percent larger on a weight basis. Effective size is obtained by passing granular material through sieves with varying dimensions of mesh and weighing the material retained by each sieve. The effective size is also approximately the average size of the grains.

EFFLUENT (EF-loo-ent) EFFLUENT

Water or other liquid — raw, partially or completely treated — flowing *FROM* a reservoir, basin, treatment process or treatment plant.

EJECTOR EJECTOR

A device used to disperse a chemical solution into water being treated.

ELECTROCHEMICAL REACTION ELECTROCHEMICAL REACTION

Chemical changes produced by electricity (electrolysis) or the production of electricity by chemical changes (galvanic action). In corrosion, a chemical reaction is accompanied by the flow of electrons through a metallic path. The electron flow may come from an external force and cause the reaction, such as electrolysis caused by a D.C. (direct current) electric railway or the electron flow may be caused by a chemical reaction as in the galvanic action of a flashlight dry cell.

ELECTROCHEMICAL SERIES ELECTROCHEMICAL SERIES

A list of metals with the standard electrode potentials given in volts. The size and sign of the electrode potential indicates how easily these elements will take on or give up electrons, or corrode. Hydrogen is conventionally assigned a value of zero.

ELECTROLYSIS (ee-leck-TRAWL-uh-sis) ELECTROLYSIS

The decomposition of material by an outside electrical current.

ELECTROLYTE (ee-LECK-tro-LIGHT) ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

ELECTROLYTIC CELL (ee-LECK-tro-LIT-ick) ELECTROLYTIC CELL

A device in which the chemical decomposition of material causes an electric current to flow. Also, a device in which a chemical reaction occurs as a result of the flow of electric current. Chlorine and caustic (NaOH) are made from salt (NaCl) in eletrolytic cells.

ELECTROMOTIVE FORCE (E.M.F.) ELECTROMOTIVE FORCE (E.M.F.)

The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. See VOLTAGE.

ELECTROMOTIVE SERIES ELECTROMOTIVE SERIES

A list of metals and alloys presented in the order of their tendency to corrode (or go into solution). Also called the Galvanic Series. This is a practical application of the theoretical ELECTROCHEMICAL SERIES.

ELECTRON ELECTRON

An extremely small, negatively charged particle; the part of an atom that determines its chemical properties.

ELEMENT ELEMENT

A substance which cannot be separated into its constituent parts and still retain its chemical identity. For example, sodium (Na) is an element.

END BELLS END BELLS

Devices used to hold the rotor and stator of a motor in position.

END POINT END POINT

Samples are titrated to the end point. This means that a chemical is added, drop by drop, to a sample until a certain color change (blue to clear, for example) occurs. This is called the END POINT of the titration. In addition to a color change, an end point may be reached by the formation of a precipitate or the reaching of a specified pH. An end point may be detected by the use of an electronic device such as a pH meter.

ENDEMIC (en-DEM-ick) ENDEMIC

Something peculiar to a particular people or locality, such as a disease which is always present in the population.

ENDRIN (EN-drin) ENDRIN

A pesticide toxic to freshwater and marine aquatic life that produces adverse health effects in domestic water supplies.

ENERGY GRADE LINE (EGL) ENERGY GRADE LINE (EGL)

A line that represents the elevation of energy head of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line (gradient) a distance equal to the velocity head ($V^2/2g$) of the water flowing at each section or point along the pipe or channel. Also see HYDRAULIC GRADE LINE.

[SEE DRAWING ON PAGE 458]

ENTERIC ENTERIC

Of intestinal origin, especially applied to wastes or bacteria.

ENTRAIN ENTRAIN

To trap bubbles in water either mechanically through turbulence or chemically through a reaction.

ENZYMES (EN-zimes) ENZYMES

Organic substances (produced by living organisms) which cause or speed up chemical reactions. Organic catalysts and/or biochemical catalysts.

E.P.A. E.P.A.

U.S. Environmental Protection Agency.

EPIDEMIC (EP-uh-DEM-ick) EPIDEMIC

A disease that occurs in a large number of people in a locality at the same time and spreads from person to person.

EPIDEMIOLOGY (EP-uh-DE-me-ALL-o-gee) EPIDEMIOLOGY

A branch of medicine which studies epidemics (diseases which affect significant numbers of people during the same time period in the same locality). The objective of epidemiology is to determine the factors that cause epidemic diseases and how to prevent them.

EPILIMNION (EP-uh-LIM-knee-on) EPILIMNION

The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature. The layer is readily mixed by wind action.

ESTER ESTER

A compound formed by the reaction between an acid and an alcohol with the elimination of a molecule of water.

EUTROPHIC (you-TRO-fick) EUTROPHIC

Reservoirs and lakes which are rich in nutrients and very productive in terms of aquatic animal and plant life.

EUTROPHICATION (you-TRO-fi-KAY-shun) EUTROPHICATION

The increase in the nutrient levels of a lake or other body of water; this usually causes an increase in the growth of aquatic animal and plant life.

EVAPORATION EVAPORATION

The process by which water or other liquid becomes a gas (water vapor or ammonia vapor).

EVAPOTRANSPIRATION (ee-VAP-o-TRANS-purr-A-shun) EVAPOTRANSPIRATION

The process by which water vapor passes into the atmosphere from living plants. Also called TRANSPIRATION.

FACULTATIVE (FACK-ul-TAY-tive) FACULTATIVE

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food material such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.

FEEDBACK FEEDBACK

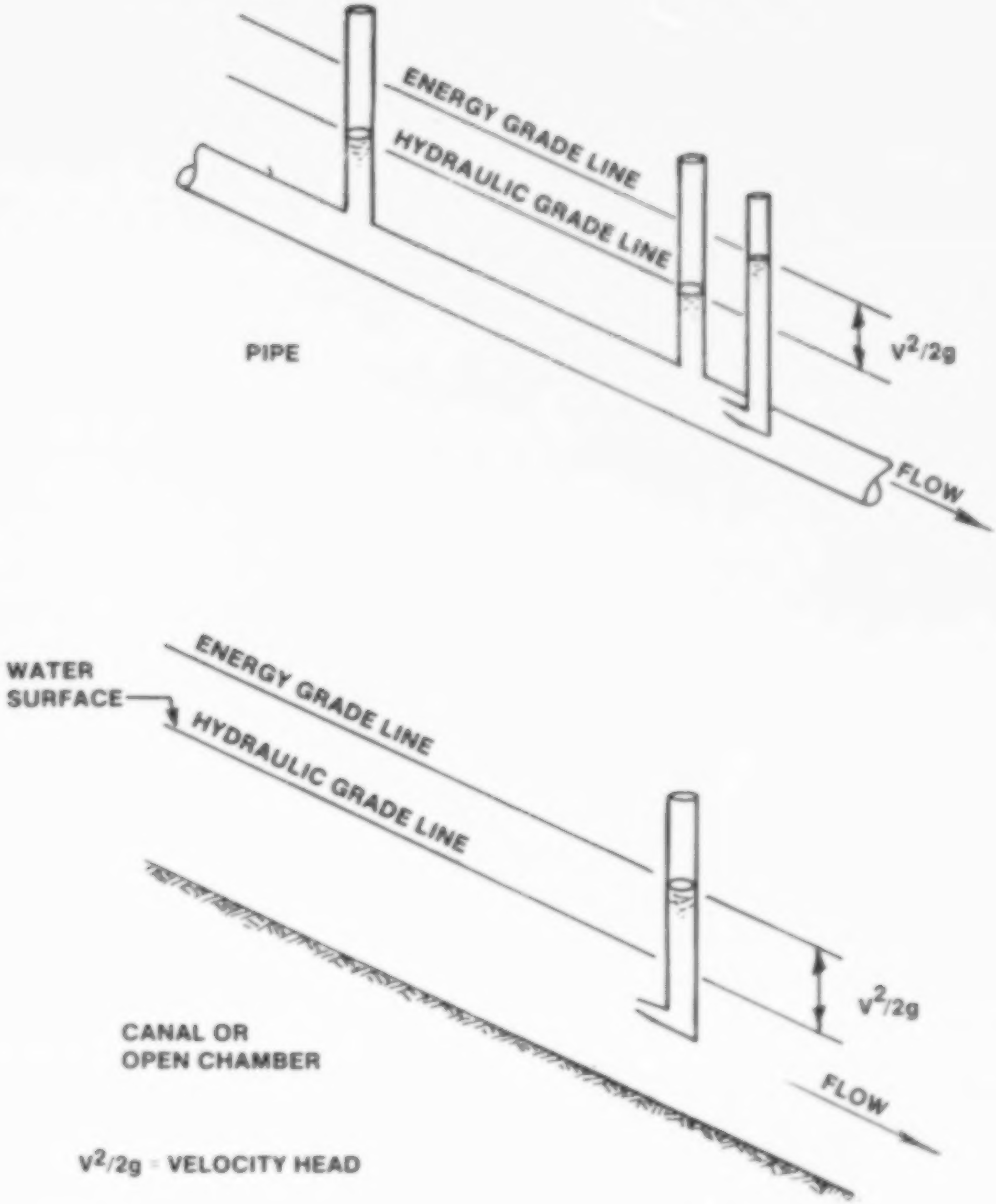
The circulating action between a sensor measuring a process variable and the controller which controls or adjusts the process variable.

FINISHED WATER FINISHED WATER

Water that has passed through a water treatment plant; all the treatment processes are completed or "finished." This water is ready to be delivered to consumers. Also called PRODUCT WATER.

FIX, SAMPLE FIX, SAMPLE

A sample is "fixed" in the field by adding chemicals that prevent the water quality indicators of interest in the sample from changing before final measurements are performed later in the lab.


ENERGY GRADE LINE
HYDRAULIC GRADE LINE
$V^2/2g$
PIPE
FLOW
WATER SURFACE
ENERGY GRADE LINE
HYDRAULIC GRADE LINE
$V^2/2g$
CANAL OR OPEN CHAMBER
FLOW
$V^2/2g$ = VELOCITY HEAD

ENERGY GRADE LINE and HYDRAULIC GRADE LINE

FLAGELLATES (FLAJ-el-LATES) FLAGELLATES

Microorganisms that move by the action of tail-like projections.

FLAME POLISHED FLAME POLISHED

Melted by a flame to smooth out irregularities. Sharp or broken edges of glass (such as the end of a glass tube) are rotated in a flame until the edge melts slightly and becomes smooth.

FLOAT ON SYSTEM FLOAT ON SYSTEM

A method of operating a water storage facility. Daily flow into the facility is approximately equal to the average daily demand for water. When consumer demands for water are low, the storage facility will be filling. During periods of high demands, the facility will be emptying.

FLOC FLOC

Clumps of bacteria and particulate impurities that have come together and formed a cluster. Found in flocculation tanks and settling or sedimentation basins.

FLOCCULATION (FLOCK-you-LAY-shun) FLOCCULATION

The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing.

FLUIDIZED (FLEW-id-I-zd) FLUIDIZED

A mass of solid particles that is made to flow like a liquid by injection of water or gas is said to have been fluidized. In water treatment, a bed of filter media is fluidized by backwashing water through the filter.

FLUORIDATION (FLOOR-uh-DAY-shun) FLUORIDATION

The addition of a chemical to increase the concentration of fluoride ions in drinking water to a predetermined optimum limit to reduce the incidence (number) of dental caries (tooth decay) in children. Defluoridation is the removal of excess fluoride in drinking water to prevent the mottling (brown stains) of teeth.

FLUSHING FLUSHING

A method used to clean water distribution lines. Hydrants are opened and water with a high velocity flows through the pipes, removes deposits from the pipes, and flows out the hydrants.

FLUX FLUX

A flowing or flow.

FOOT VALVE FOOT VALVE

A special type of check valve located at the bottom end of the suction pipe on a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

FREE AVAILABLE RESIDUAL CHLORINE FREE AVAILABLE RESIDUAL CHLORINE

That portion of the total available residual chlorine composed of dissolved chlorine gas (Cl_2), hypochlorous acid ($HOCl$), and/or hypochlorite ion (OCl^-) remaining in water after chlorination. This does not include chlorine that has combined with ammonia, nitrogen, or other compounds.

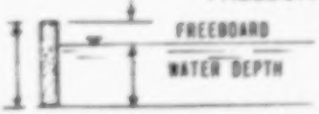
FREE RESIDUAL CHLORINATION FREE RESIDUAL CHLORINATION

The application of chlorine to water to produce a free available chlorine residual equal to at least 80 percent of the total residual chlorine (sum of free and combined available chlorine residual).

FREEBOARD FREEBOARD

(1) The vertical distance from the normal water surface to the top of the confining wall.

(2) The vertical distance from the sand surface to the underside of a trough in a sand filter. This distance is also called AVAILABLE EXPANSION.



FRICTION LOSSES FRICTION LOSSES

The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses. Also see HEAD LOSS.

FUNGI (FUN-ji) FUNGI

Mushrooms, molds, mildews, rusts, and smuts that are small non-chlorophyll-bearing plants lacking roots, stems and leaves. They occur in natural waters and grow best in the absence of light. Their decomposition may cause objectionable tastes and odors in water.

GAGE PRESSURE

GAGE PRESSURE

The pressure within a closed container or pipe as measured with a gage. In contrast, absolute pressure is the sum of atmospheric pressure (14.7 lbs/sq in) *PLUS* pressure within a vessel (as measured by a gage). Most pressure gages read in "gage pressure" or psig (**p**ounds per **s**quare inch **g**age pressure).

GALVANIC CELL

GALVANIC CELL

An eletrolytic cell capable of producing electrical energy by electrochemical action. The decomposition of materials in the cell causes an electric (electron) current to flow from cathode to anode.

GALVANIC SERIES

GALVANIC SERIES

A list of metals and alloys presented in the order of their tendency to corrode (or go into solution). Also called the ELECTROMOTIVE SERIES. This is a practical application of the theoretical ELECTROCHEMICAL SERIES.

GALVANIZE

GALVANIZE

To coat a metal (especially iron or steel) with zinc. Galvanization is the process of coating a metal with zinc.

GARNET (GAR-nit)

GARNET

A group of hard, reddish, glassy, mineral sands made up of silicates of base metals (calcium, magnesium, iron and manganese). Garnet has a higher density than sand.

GAUGE PIPE

GAUGE PIPE

A number that defines the thickness of the sheet used to make steel pipe. The larger the number, the thinner the pipe wall.

GEOLOGICAL LOG

GEOLOGICAL LOG

A detailed description of all underground features discovered during the drilling of a well (depth, thickness and type of formations).

GEOPHYSICAL LOG

GEOPHYSICAL LOG

A record of the structure and composition of the earth encountered when drilling a well or similar type of test hole or boring.

GERMICIDE (GERM-uh-SIDE)

GERMICIDE

A substance formulated to kill germs or microorganisms. The germicidal properties of chlorine make it an effective disinfectant.

GIARDIASIS (gee-are-DYE-uh-sis)

GIARDIASIS

Intestinal disease caused by an infestation of Giardia flagellates.

GRAB SAMPLE

GRAB SAMPLE

A single sample collected at a particular time and place which represents the composition of the water only at that time and place.

GRADE

GRADE

(1) The elevation of the invert (lowest point) of the bottom of a pipeline, canal, culvert or similar conduit.

(2) The inclination or slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5 percent grade would be a drop of one-half foot per hundred feet of pipe.

GRAVIMETRIC

GRAVIMETRIC

A means of measuring unknown concentrations of water quality indicators in a sample by WEIGHING a precipitate or residue of the sample.

GREENSAND

GREENSAND

A sand which looks like ordinary filter sand except that it is green in color. This sand is a natural ion exchange mineral which is capable of softening water.

HARD WATER

HARD WATER

Water having a high concentration of calcium and magnesium ions. A water may be considered hard if it has a hardness greater than the typical hardness of water from the region. Some textbooks define hard water as water with a hardness of more than 100 mg/*L* as calcium carbonate.

HARDNESS, WATER

HARDNESS, WATER

A characteristic of water caused mainly by the salts of calcium and magnesium, such as bicarbonate, carbonate, sulfate, chloride and nitrate. Excessive hardness in water is undesirable because it causes the formation of soap curds, increased use of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes causes objectionable tastes in drinking water.

HEAD HEAD

The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

HEAD LOSS HEAD LOSS

The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls or restrictions caused by fittings. Water flowing in a pipe loses head, pressure or energy as a result of friction losses. Also see FRICTION LOSSES.

HEADER HEADER

A large pipe to which a series of smaller pipes are connected. Also called a MANIFOLD.

HEAT SENSOR HEAT SENSOR

A device that opens and closes a switch in response to changes in the temperature. This device might be a metal contact, or a thermocouple which generates a minute electrical current proportional to the difference in heat, or a variable resistor whose value changes in response to changes in temperature. Also called a TEMPERATURE SENSOR.

HECTARE (HECK-tar) HECTARE

A measure of area in the metric system similar to an acre. One hectare is equal to 10,000 square meters and 2.4711 acres.

HEPATITIS (HEP-up-TIE-tis) HEPATITIS

Hepatitis is an inflammation of the liver usually caused by an acute viral infection. Yellow jaundice is one symptom of hepatitis.

HERBICIDE (HERB-uh-SIDE) HERBICIDE

A compound, usually a man-made organic chemical, used to kill or control plant growth.

HERTZ HERTZ

The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit. Also called the frequency of the current. Abbreviated Hz.

HIGH-LINE JUMPERS HIGH-LINE JUMPERS

Pipes or hoses connected to fire hydrants and laid on top of the ground to provide emergency water service for an isolated portion of a distribution system.

HOSE BIB HOSE BIB

Faucet. A location in a water line where a hose is connected.

HTH (pronounce as separate letters) HTH

High **T**est **H**ypochlorite. Calcium hypochlorite or $Ca(OCl)_2$

HYDRATED LIME HYDRATED LIME

Limestone that has been "burned" and treated with water under controlled conditions until the calcium oxide portion has been converted to calcium hydroxide ($Ca(OH)_2$). Hydrated lime is quicklime combined with water. $CaO + H_2O \rightarrow Ca(OH)_2$. Also see QUICKLIME.

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile or water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small vertical tube connected to the pipe. Also see ENERGY GRADE LINE.

[SEE DRAWING ON PAGE 458]

HYDRAULIC GRADIENT HYDRAULIC GRADIENT

The slope of the hydraulic grade line. This is the slope of the water surface in an open channel, the slope of the water surface of the groundwater table, or the slope of the water pressure for pipes under pressure.

HYDROGEOLOGIST (HI-dro-gee-ALL-uh-gist) HYDROGEOLOGIST

A person who studies and works with groundwater.

HYDROLOGIC CYCLE (HI-dro-LOJ-ick) HYDROLOGIC CYCLE

The process of evaporation of water into the air and its return to Earth by precipitation (rain or snow). This process also includes transpiration from plants, groundwater movement, and runoff into rivers, streams and the ocean. Also called the WATER CYCLE.

HYDROLYSIS (hi-DROLL-uh-sis) HYDROLYSIS

A chemical reaction in which a compound is converted into another compound by taking up water.

HYDROPHILIC (HI-dro-FILL-ick) HYDROPHILIC

Having a strong affinity (liking) for water. The opposite of HYDROPHOBIC.

HYDROPHOBIC (HI-dro-FOE-bick) HYDROPHOBIC

Having a strong aversion (dislike) for water. The opposite of HYDROPHILIC.

HYDROPNEUMATIC (HI-dro-new-MAT-ick) HYDROPNEUMATIC

A water system, usually small, in which a water pump is automatically controlled (started and stopped) by the air pressure in a compressed-air tank.

HYDROSTATIC PRESSURE (HI-dro-STAT-ick) HYDROSTATIC PRESSURE

(1) The pressure at a specific elevation exerted by a body of water at rest, or

(2) In the case of groundwater, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation.

HYPOCHLORINATION (HI-poe-KLOR-uh-NAY-shun) HYPOCHLORINATION

The application of hypochlorite compounds to water for the purpose of disinfection.

HYPOCHLORINATORS (HI-poe-KLOR-uh-NAY-tors) HYPOCHLORINATORS

Chlorine pumps, chemical feed pumps or devices used to dispense chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite into the water being treated.

HYPOCHLORITE (HI-poe-KLOR-ite) HYPOCHLORITE

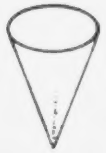
Chemical compounds containing available chlorine; used for disinfection. They are available as liquids (bleach) or solids (powder, granules and pellets). Salts of hypochlorous acid.

HYPOLIMNION (HI-poe-LIM-knee-on) HYPOLIMNION

The lowest layer in a thermally stratified lake or reservoir. This layer consists of colder, more dense water, has a constant temperature and no mixing occurs.

IMHOFF CONE IMHOFF CONE

A clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume (usually one liter) of water.



IMPELLER IMPELLER

A rotating set of vanes in a pump designed to pump or lift water.

IMPERMEABLE (im-PURR-me-uh-BULL) IMPERMEABLE

Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.

INDICATOR (CHEMICAL) INDICATOR (CHEMICAL)

A substance that gives a visible change, usually of color, at a desired point in a chemical reaction, generally at a specified end point.

INDICATOR (INSTRUMENT) INDICATOR (INSTRUMENT)

A device which indicates the result of a measurement. Most indicators in the water utility field use either a fixed scale and movable indicator (pointer) such as a pressure gage or a movable scale and movable indicator like those used on a circular-flow recording chart. Also called a RECEIVER.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The gradual flow or movement of water into and through (to percolate or pass through) the pores of the soil. Also called PERCOLATION.

INFLUENT (IN-flu-ent) INFLUENT

Water or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process or treatment plant.

IN-LINE FILTRATION IN-LINE FILTRATION

The addition of chemical coagulants directly to the filter inlet pipe. The chemicals are mixed by the flowing water. Flocculation and sedimentation facilities are eliminated. This pretreatment method is commonly used in pressure filter installation. Also see CONVENTIONAL FILTRATION and DIRECT FILTRATION.

INORGANIC INORGANIC

Material such as sand, salt, iron, calcium salts and other mineral materials. Inorganic substances are of mineral origin, whereas organic substances are usually of animal or plant origin. Also see ORGANIC.

INPUT HORSEPOWER INPUT HORSEPOWER

The total power used in operating a pump and motor.

$$\text{Input Horsepower, HP} = \frac{(\text{Brake Horsepower,HP})(100\%)}{\text{Motor Efficiency, \%}}$$

INSECTICIDE INSECTICIDE

Any substance or chemical formulated to kill or control insects.

INTEGRATOR INTEGRATOR

A device or meter that continuously measures and calculates (adds) total flows in gallons, or million cubic feet, or some other unit of volume measurement. Also called a TOTALIZER.

INTERFACE INTERFACE

The common boundary layer between two substances such as water and a solid (metal); or between two fluids such as water and a gas (air); or between a liquid (water) and another liquid (oil).

INTERLOCK INTERLOCK

An electrical switch, usually magnetically operated. Used to interrupt all (local) power to a panel or device when the door is opened or the circuit exposed to service.

INTERNAL FRICTION INTERNAL FRICTION

Friction within a fluid (water) due to cohesive forces.

INTERSTICE (in-TUR-stuhz) INTERSTICE

A very small open space in a rock or granular material. Also called a void or void space. Also see PORE.

INVERT (IN-vert) INVERT

The lowest point of the channel inside a pipe, conduit, or canal.

ION ION

An electrically charged atom, radical (such as SO_4^{2-}), or molecule formed by the loss or gain of one or more electrons.

IONIC CONCENTRATION IONIC CONCENTRATION

The concentration of any ion in solution, usually expressed in moles per liter.

IONIZATION (EYE-on-uh-ZAY-shun) IONIZATION

The splitting or dissociation (separation) of molecules into negatively and positively charged ions.

JAR TEST JAR TEST

A laboratory procedure that simulates a water treatment plant's coagulation/flocculation units with differing chemical doses and also energy of rapid mix, energy of slow mix, and settling time. The purpose of this procedure is to *ESTIMATE* the minimum or ideal coagulant dose required to achieve certain water quality goals. Samples of water to be treated are commonly placed in six jars. Various amounts of chemicals are added to each jar, stirred and the settling of solids is observed. The dose of chemicals that provides satisfactory settling removal of turbidity and/or color is the dose used to treat the water being taken into the plant at that time. When evaluating the results of a jar test, the operator should also consider the floc quality in the flocculation area and the floc loading on the filter.

JOGGING JOGGING

The frequent starting and stopping of an electric motor.

JOULE (jewel) JOULE

A measure of energy, work or quantity of heat. One joule is the work done when the point of application of a force of one newton is displaced a distance of one meter in the direction of force.

KELLY KELLY

The square section of a rod which causes the rotation of the drill bit. Torque from a drive table is applied to the square rod to cause the rotary motion. The drive table is chain or gear driven by an engine.

KILO KILO

(1) Kilogram.

(2) Kilometer.

(3) A prefix meaning "thousand" used in the metric system and other scientific systems of measurement.

KINETIC ENERGY KINETIC ENERGY

Energy possessed by a moving body of matter, such as water, as a result of its motion.

KJELDAHL NITROGEN (KELL-doll) KJELDAHL NITROGEN

Nitrogen in the form of organic proteins or their decomposition product ammonia, as measured by the Kjeldahl Method.

LANGELIER INDEX (L.I.) LANGELIER INDEX (L.I.)

An index reflecting the equilibrium pH of a water with respect to calcium and alkalinity. This index is used in stabilizing water to control both corrosion and the deposition of scale.

Langelier Index = $pH - pH_s$
where pH = actual pH of the water, and
pH_s = pH at which the water, having the same alkalinity and calcium content, is just saturated with calcium carbonate.

LAUNDERING WEIR (LAWN-der-ing weer) LAUNDERING WEIR

Sedimentation basin overflow weir. A plate with V-notches along the top to assure a uniform flow rate and avoid short-circuiting.

LAUNDERS (LAWN-ders) LAUNDERS

Sedimentation basin and filter discharge channels, consisting of overflow weir plates (in sedimentation basins) and conveying troughs.

LEATHERS LEATHERS

O rings or gaskets used with piston pumps to provide a seal between the piston and the side wall.

LEVEL CONTROLS LEVEL CONTROLS

A float device (or pressure switch) which senses changes in a measured variable and opens or closes a switch in response to that change. In its simplest form, this control might be a floating ball connected mechanically to a switch or valve such as is used to stop water flow into a toilet when the tank is full.

LINDANE (LYNN-dane) LINDANE

A pesticide that causes adverse health effects in domestic water supplies and also is toxic to freshwater and marine aquatic life.

LINEARITY (LYNN-ee-AIR-it-ee) LINEARITY

How closely an instrument measures actual values of a variable through its effective range; a measure used to determine the accuracy of an instrument.

LITTORAL ZONE (LIT-or-al) LITTORAL ZONE

(1) That portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants.

(2) The strip of land along the shoreline between the high and low water levels.

LOGARITHM (LOG-a-rith-m) LOGARITHM

The exponent that indicates the power to which a number must be raised to produce a given number. For example: if $B^2 = N$, the 2 is the logarithm of N (to the base B), or $10^2 = 100$ and $\log_{10} 100 = 2$. Also abbreviated to "log."

LOGGING, ELECTRICAL LOGGING, ELECTRICAL

A procedure used to determine the porosity (spaces or voids) of formations in search of water-bearing formations (aquifers). Electrical probes are lowered into wells, an electrical current is induced at various depths, and the resistance measured of various formations indicates the porosity of the material.

M or MOLAR
M or MOLAR

A molar solution consists of one gram molecular weight of a compound dissolved in enough water to make one liter of solution. A gram molecular weight is the molecular weight of a compound in grams. For example, the molecular weight of sulfuric acid (H_2SO_4) is 98. A one *M* solution of sulfuric acid would consist of 98 grams of H_2SO_4 dissolved in enough distilled water to make one liter of solution.

MACROSCOPIC (MACK-row-SKAWP-ick) ORGANISMS
MACROSCOPIC ORGANISMS

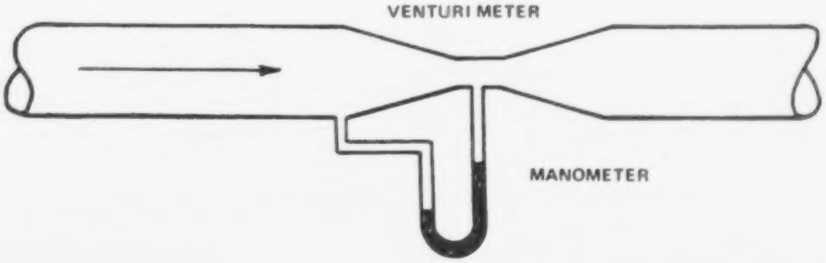
Organisms big enough to be seen by the eye without the aid of a microscope.

MANIFOLD
MANIFOLD

A large pipe to which a series of smaller pipes are connected. Also called a HEADER.

MANOMETER (man-NAH-mut-ter)
MANOMETER

An instrument for measuring pressure. Usually, a manometer is a glass tube filled with a liquid that is used to measure the difference in pressure across a flow-measuring device such as an orifice or Venturi meter. The instrument used to measure blood pressure is a type of manometer.



MATERIAL SAFETY DATA SHEET (MSDS)
MATERIAL SAFETY DATA SHEET (MSDS)

A document which provides pertinent information and a profile of a particular hazardous substance or mixture. An MSDS is normally developed by the manufacturer or formulator of the hazardous substance or mixture. The MSDS is required to be made available to employers and operators whenever there is the likelihood of the hazardous substance or mixture being introduced into a workplace.

MAXIMUM CONTAMINANT LEVEL (MCL)
MAXIMUM CONTAMINANT LEVEL (MCL)

See MCL.

MBAS
MBAS

Methylene - **B**lue - **A**ctive **S**ubstances. These substances are used in surfactants or detergents.

MCL
MCL

Maximum **C**ontaminant **L**evel. The largest allowable amount. MCLs for various water quality indicators are specified in the National Interim Primary Drinking Water Regulations (NIPDWR).

MEASURED VARIABLE
MEASURED VARIABLE

A characteristic or component part that is sensed and quantified (reduced to a reading of some kind) by a primary element or sensor.

MECHANICAL JOINT
MECHANICAL JOINT

A flexible device that joins pipes or fittings together by the use of lugs and bolts.

MEG
MEG

A procedure used for checking the insulation resistance on motors, feeders, buss bar systems, grounds, and branch circuit wiring. Also see MEGGER.

MEGGER (from megohm)
MEGGER

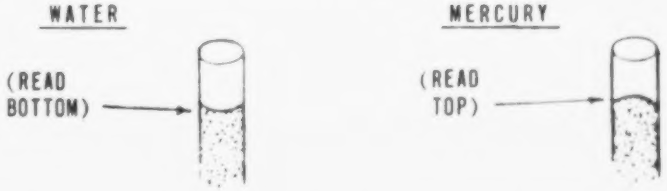
An instrument used for checking the insulation resistance on motors, feeders, buss bar systems, grounds, and branch circuit wiring. Also see MEG.

MEGOHM
MEGOHM

Meg means one million, so 5 megohms means 5 million ohms. A megger reads in millions of ohms.

MENISCUS (meh-NIS-cuss) MENISCUS

The curved top of a column of liquid (water, oil, mercury) in a small tube. When the liquid wets the sides of the container (as with water), the curve forms a valley. When the confining sides are not wetted (as with mercury), the curve forms a hill or upward bulge.



MESH MESH

One of the openings or spaces in a screen or woven fabric. The value of the mesh is usually given as the number of openings per inch. This value does not consider the diameter of the wire or fabric; therefore, the mesh number does not always have a definite relationship to the size of the hole.

MESOTROPHIC (MESS-o-TRO-fick) MESOTROPHIC

Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.

METABOLISM (meh-TAB-uh-LIZ-um) METABOLISM

(1) The biochemical processes in which food is used and wastes are formed by living organisms.

(2) All biochemical reactions involved in cell formation and growth.

METALIMNION (MET-uh-LIM-knee-on) METALIMNION

The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. Also called the THERMOCLINE.

METHOXYCHLOR (meth-OXY-klor) METHOXYCHLOR

A pesticide which causes adverse health effects in domestic water supplies and is also toxic to freshwater and marine aquatic life. The chemical name for methoxychlor is 2,2-bis (p-methoxyphenol)-1,1,1-trichloroethane.

METHYL ORANGE ALKALINITY METHYL ORANGE ALKALINITY

A measure of the total alkalinity in a water sample. The alkalinity is measured by the amount of standard sulfuric acid required to lower the pH of the water to a pH level of 4.5, as indicated by the change in color of methyl orange from orange to pink. Methyl orange alkalinity is expressed as milligrams per liter equivalent calcium carbonate.

mg/*L* mg/*L*

See MILLIGRAMS PER LITER.

MICROBIAL GROWTH (my-KROW-bee-ul) MICROBIAL GROWTH

The activity and growth of microorganisms such as bacteria, algae, diatoms, plankton and fungi.

MICRON (MY-kron) MICRON

A unit of length. One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.

MICROORGANISMS (MY-crow-OR-gan-IS-zums) MICROORGANISMS

Living organisms that can be seen individually only with the aid of a microscope.

MIL MIL

A unit of length equal to 0.001 of an inch. The diameter of wires and tubing is measured in mils, as is the thickness of plastic sheeting.

MILLIGRAMS PER LITER, mg/*L* MILLIGRAMS PER LITER, mg/*L*

A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/*L* of a substance in fresh water is equal to one part per million parts (ppm). Thus a liter of water with a specific gravity of 1.0 weighs one million milligrams. If it contains 10 milligrams of calcium, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/*L*), or 10 parts of calcium per million parts of water, or 10 parts per million (10 ppm).

MILLIMICRON (MILL-uh-MY-kron) MILLIMICRON

A unit of length equal to $10^{-3}\mu$ (one thousandth of a micron), 10^{-6} millimeters, or 10^{-9} meters; correctly called a nanometer, nm.

MOLAR MOLAR

See **M** for MOLAR.

MOLE MOLE

The molecular weight of a substance, usually expressed in grams.

MOLECULAR WEIGHT MOLECULAR WEIGHT

The molecular weight of a compound in grams is the sum of the atomic weights of the elements in the compound. The molecular weight of sulfuric acid (H_2SO_4) in grams is 98.

Element	Atomic Weight	Number of Atoms	Molecular Weight
H	1	2	2
S	32	1	32
O	16	4	64
			98

MOLECULE (MOLL-uh-KULE) MOLECULE

The smallest division of a compound that still retains or exhibits all the properties of the substance.

MONOMER (MON-o-MER) MONOMER

A molecule of low molecular weight capable of reacting with identical or different monomers to form polymers.

MONOMICTIC (mo-no-MICK-tick) MONOMICTIC

Lakes and reservoirs which are relatively deep, do not freeze over during the winter months, and undergo a single stratification and mixing cycle during the year. These lakes and reservoirs usually become destratified during the mixing cycle, usually in the fall of the year.

MONOVALENT MONOVALENT

Having a valence of one, such as the cuprous (copper) ion, Cu^+.

MOST PROBABLE NUMBER (MPN) MOST PROBABLE NUMBER (MPN)

See MPN.

MOTILE (MO-till) MOTILE

Capable of self-propelled movement. A term that is sometimes used to distinguish between certain types of organisms found in water.

MOTOR EFFICIENCY MOTOR EFFICIENCY

The ratio of energy delivered by a motor to the energy supplied to it during a fixed period or cycle. Motor efficiency ratings will vary depending upon motor manufacturer and usually will range from 88.9 to 90.0 percent.

MPN (pronounce as separate letters) MPN

MPN is the Most Probable Number of coliform-group organisms per unit volume of sample water. Expressed as the number of organisms per 100 m*L* of sample water.

MUDBALLS MUDBALLS

Material that is approximately round in shape and varies from pea-sized up to two or more inches in diameter. This material forms in filters and gradually increases in size when not removed by the backwashing process.

MULTI-STAGE PUMP MULTI-STAGE PUMP

A pump that has more than one impeller. A single-stage pump has one impeller.

N or NORMAL **N** or NORMAL

A normal solution contains one gram equivalent weight of reactant (compound) per liter of solution. The equivalent weight of an acid is that weight which contains one gram atom of ionizable hydrogen or its chemical equivalent. For example, the equivalent weight of sulfuric acid (H_2SO_4) is 49 (98 divided by 2 because there are two replaceable hydrogen ions). A one *N* solution of sulfuric acid would consist of 49 grams of H_2SO_4 dissolved in enough water to make one liter of solution.

NATIONAL ENVIRONMENTAL TRAINING ASSOCIATION NATIONAL ENVIRONMENTAL TRAINING ASSOCIATION

A professional organization devoted to serving the environmental trainer and promoting better operation of waterworks and pollution control facilities. For information on NETA membership and publications, contact NETA, 8687 Via de Ventura, Suite 214, Scottsdale, Arizona 85258.

NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH — NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH

See NIOSH.

NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS — NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

Commonly referred to as NIPDWR.

NATIONAL SAFE DRINKING WATER REGULATIONS — NATIONAL SAFE DRINKING WATER REGULATIONS

Commonly referred to as NSDWR.

NEPHELOMETRIC (NEFF-el-o-MET-rick) — NEPHELOMETRIC

A means of measuring turbidity in a sample by using an instrument called a nephelometer. A nephelometer passes light through a sample and the amount of light deflected (usually at a 90-degree angle) is then measured.

NETA — NETA

See **N**ational **E**nvironmental **T**raining **A**ssociation.

NEWTON — NEWTON

A force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one meter per second per second.

NIOSH — NIOSH

The **N**ational **I**nstitute of **O**ccupational **S**afety and **H**ealth is an organization that tests and approves safety equipment for particular applications. NIOSH is the primary Federal agency engaged in research in the national effort to eliminate on-the-job hazards to the health and safety of working people. The NIOSH Publications Catalog contains a listing of NIOSH publications mainly on industrial hygiene and occupational health. To obtain a copy of the catalog, write to NIOSH Publications, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

NIPDWR — NIPDWR

National **I**nterim **P**rimary **D**rinking **W**ater **R**egulations.

NITROGENOUS (nye-TRAH-jen-us) — NITROGENOUS

A term used to describe chemical compounds (usually organic) containing nitrogen in combined forms. Proteins and nitrates are nitrogenous compounds.

NOBLE METAL — NOBLE METAL

A chemically inactive metal (such as gold). A metal that does not corrode easily and is much scarcer (and more valuable) than the so-called useful or base metals. Also see BASE METAL.

NOMINAL DIAMETER — NOMINAL DIAMETER

An approximate measurement of the diameter of a pipe. Although the nominal diameter is used to describe the size or diameter of a pipe, it is usually not the exact inside diameter of the pipe.

NONIONIC POLYMER (NON-eye-ON-ick) — NONIONIC POLYMER

A polymer that has no net eletrical charge.

NONPOINT SOURCE — NONPOINT SOURCE

A runoff or discharge from a field or similar source. A point source refers to a discharge that comes out the end of a pipe.

NONPOTABLE (non-POE-tuh-bull) — NONPOTABLE

Water that may contain objectionable pollution, contamination, minerals, or infective agents and is considered unsafe and/or unpalatable for drinking.

NORMAL — NORMAL

See **N** for NORMAL.

NPDES PERMIT — NPDES PERMIT

National **P**ollutant **D**ischarge **E**limination **S**ystem permit is the regulatory agency document designed to control all discharges of pollutants from point sources in U.S. waterways. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows.

NSDWR NSDWR

National **S**afe **D**rinking **W**ater **R**egulations.

NUTRIENT NUTRIENT

Any substance that is assimilated (taken in) by organisms and promotes growth. Nitrogen and phosphorous are nutrients which promote the growth of algae. There are other essential and trace elements which are also considered nutrients.

OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970 OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970

See OSHA.

ODOR THRESHOLD ODOR THRESHOLD

The minimum odor of a water sample that can just be detected after successive dilutions with odorless water. Also called THRESHOLD ODOR.

OFFSET (or DROOP) OFFSET

The difference between the actual value and the desired value (or set point); characteristic of proportional controllers that do not incorporate reset action.

OHM OHM

The unit of electrical resistance. The resistance of a conductor in which one volt produces a current of one ampere.

OLFACTORY FATIGUE (oh-FAK-tore-ee) OLFACTORY FATIGUE

A condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.

OLIGOTROPHIC (AH-lig-o-TRO-fick) OLIGOTROPHIC

Reservoirs and lakes which are nutrient poor and contain little aquatic plant or animal life.

ORGANIC ORGANIC

Substances that come from animal or plant sources. Organic substances always contain carbon. (Inorganic materials are chemical substances of mineral origin.) Also see INORGANIC.

ORGANICS ORGANICS

(1) A term used to refer to chemical compounds made from carbon molecules. These compounds may be natural materials (such as animal or plant sources) or man-made materials (such as synthetic organics). Also see ORGANIC.

(2) Any form of animal of plant life. Also see BACTERIA.

ORGANISM ORGANISM

Any form of animal or plant life. Also see BACTERIA.

ORIFICE (OR-uh-fiss) ORIFICE

An opening (hole) in a plate, wall or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe.

ORP ORP

Oxidation-**R**eduction **P**otential. The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant); used as a qualitative measure of the state of oxidation in water treatment systems.

ORTHOTOLIDINE (or-tho-TOL-uh-dine) ORTHOTOLIDINE

Orthotolidine is a colorimetric indicator of chlorine residual. If chlorine is present, a yellow-colored compound is produced. This reagent is no longer approved for chemical analysis.

OSHA (O-shuh) OSHA

The Williams-Steiger **O**ccupational **S**afety and **H**ealth **A**ct of 1970 (OSHA) is a law designed to protect the health and safety of industrial workers and also the operators of water supply systems and treatment plants.

OSMOSIS (oz-MOE-sis) OSMOSIS

The passage of a liquid from a weak solution to a more concentrated solution across a semipermeable membrane. The membrane allows the passage of the solvent (water) but not the dissolved solids (solutes). This process tends to equalize the conditions on either side of the membrane.

OVERALL EFFICIENCY, PUMP OVERALL EFFICIENCY, PUMP

The combined efficiency of a pump and motor together. Also called the WIRE-TO-WATER EFFICIENCY.

OVERDRAFT OVERDRAFT

The pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin. This pumping results in a depletion or "mining" of the groundwater in the basin.

OVERFLOW RATE OVERFLOW RATE

One of the guidelines for the design of settling tanks and clarifiers in treatment plants. Used by operators to determine if tanks and clarifiers are hydraulically (flow) over- or underloaded. Also called SURFACE LOADING.

$$\text{Overflow Rate, GDP/sq ft} = \frac{\text{Flow, gallons/day}}{\text{Surface Area, sq ft}}$$

OVERTURN OVERTURN

The almost spontaneous mixing of all layers of water in a reservoir or lake when the water temperature becomes similar from top to bottom. This may occur in the fall/winter when the surface waters cool to the same temperature as the bottom waters and also in the spring when the surface waters warm after the ice melts.

OXIDATION (ox-uh-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In the environment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

OXIDATION-REDUCTION POTENTIAL OXIDATION-REDUCTION POTENTIAL

The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant); used as a qualitative measure of the state of oxidation in water treatment systems.

OXIDIZING AGENT OXIDIZING AGENT

Any substance, such as oxygen (O_2) or chlorine (Cl_2), that will readily add (take on) electrons. The opposite is a REDUCING AGENT.

OXYGEN DEFICIENCY OXYGEN DEFICIENCY

An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

OZONATION (O-zoe-NAY-shun) OZONATION

The application of ozone to water for disinfection or for taste and odor control.

PACKER ASSEMBLY PACKER ASSEMBLY

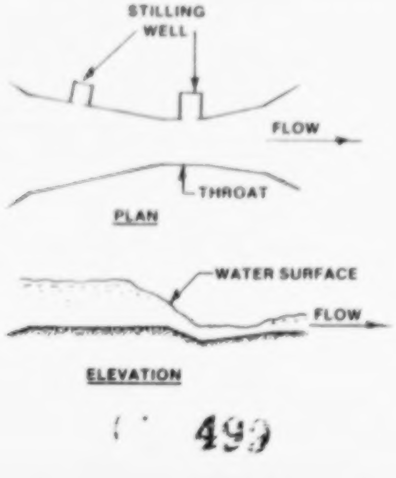
An inflatable device used to seal the tremie pipe inside the well casing to prevent the grout from entering the inside of the conductor casing.

PALATABLE (PAL-a-ta-ble) PALATABLE

Water at a desirable temperature that is free from objectionable tastes, odors, colors, and turbidity. Pleasing to the senses.

PARSHALL FLUME PARSHALL FLUME

A device used to measure the flow in an open channel. The flume narrows to a throat of fixed dimensions and then expands again. The rate of flow can be calculated by measuring the difference in head (pressure) before and at the throat of the flume.



PARTICLE COUNT **PARTICLE COUNT**

The results of a microscopic examination of treated water with a special "particle counter" which classifies suspended particles by number and size.

PARTICULATE (par-TICK-you-let) **PARTICULATE**

A very small solid suspended in water which can vary widely in size, shape, density, and electrical charge. Colloidal and dispersed particulates are artificially gathered together by the processes of coagulation and flocculation.

PARTS PER MILLION (PPM) **PARTS PER MILLION (PPM)**

Parts per million parts, a measurement of concentration on a weight or volume basis. This term is equivalent to milligrams per liter (mg/*L*) which is the preferred term.

PASCAL **PASCAL**

The pressure or stress of one newton per square meter. (Abbreviated Pa)

$$1 \text{ psi} = 6895 \text{ Pa} = 6.895 \text{ kN/sq m} = 0.0703 \text{ kg/sq cm}$$

PATHOGENIC ORGANISMS (path-o-JEN-ick) **PATHOGENIC ORGANISMS**

Organisms, including bacteria, viruses or cysts, capable of causing diseases (typhoid, cholera, dysentery) in a host (such as a person). There are many types of organisms which do *NOT* cause disease. These organisms are called non-pathogenic.

PATHOGENS (PATH-o-jens) **PATHOGENS**

Pathogenic or disease-causing organisms.

PCBs **PCBs**

See POLYCHLORINATED BIPHENYLS.

PEAK DEMAND **PEAK DEMAND**

The maximum momentary load placed on a water treatment plant, pumping station or distribution system. This demand is usually the maximum average load in one hour or less, but may be specified as the instantaneous or with some other short time period.

PERCENT SATURATION **PERCENT SATURATION**

The amount of a substance that is dissolved in a solution compared with the amount that could be dissolved in the solution, expressed as a percent.

$$\text{Percent Saturation, \%} = \frac{\text{Amount of Substance That is Dissolved}}{\text{Amount That Could Be Dissolved in Solution}} \times 100\%$$

PERCOLATING WATER (PURR-co-LAY-ting) **PERCOLATING WATER**

Water that passes through soil or rocks under the force of gravity.

PERCOLATION (PURR-ko-LAY-shun) **PERCOLATION**

The slow passage of water through a filter medium; or, the gradual penetration of soil and rocks by water.

PERIPHYTON (puh-RIF-uh-tawn) **PERIPHYTON**

Microscopic plants and animals that are firmly attached to solid surfaces under water such as rocks, logs, pilings and other structures.

PERMEABILITY (PURR-me-uh-BILL-uh-tee) **PERMEABILITY**

The property of a material or soil that permits considerable movement of water through it when it is saturated.

PERMEATE (PURR-me-ate) **PERMEATE**

To penetrate and pass through, as water penetrates and passes through soil and other porous materials.

PESTICIDE **PESTICIDE**

Any substance or chemical designed or formulated to kill or control weeds or animal pests. Also see ALGICIDE, HERBICIDE, INSECTICIDE,and RODENTICIDE.

PET COCK **PET COCK**

A small valve or faucet used to drain a cylinder or fitting.

pH (pronounce as separate letters) pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion activity.

$$\text{pH} = \text{Log} \frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is most acid, 14 most basic, and 7 neutral. Natural waters usually have a pH between 6.5 and 8.5.

PHENOLIC COMPOUNDS (FEE-noll-LICK) PHENOLIC COMPOUNDS

Organic compounds that are derivatives of benzene.

PHENOLPHTHALEIN ALKALINITY (FEE-nol-THAY-leen) PHENOLPHTHALEIN ALKALINITY

The alkalinity in a water sample measured by the amount of standard acid required to lower the pH to a level of 8.3, as indicated by the change in color of phenolphthalein from pink to clear. Phenolphthalein alkalinity is expressed as milligrams per liter equivalent calcium carbonate.

PHOTOSYNTHESIS (foe-tow-SIN-thuh-sis) PHOTOSYNTHESIS

A process in which organisms, with the aid of chlorophyll (green plant enzyme), convert carbon dioxide and inorganic substances into oxygen and additional plant material, using sunlight for energy. All green plants grow by this process.

PHYTOPLANKTON (FI-tow-PLANK-ton) PHYTOPLANKTON

Small, usually microscopic plants (such as algae), found in lakes, reservoirs, and other bodies of water.

PICO PICO

A prefix used in the metric system and other scientific systems of measurement which means 10^{-12} or 0.000 000 000 001.

PICOCURIE PICOCURIE

A measure of radioactivity. One picoCurie of radioactivity is equivalent to 0.037 nuclear disintegrations per second.

PITLESS ADAPTER PITLESS ADAPTER

A fitting which allows the well casing to be extended above ground while having a discharge connection located below the frost line. Advantages of using a pitless adapter include the elimination of the need for a pit or pump house and it is a water-tight design, which helps maintain a sanitary water supply.

PLAN VIEW PLAN VIEW

A diagram or photo showing a facility as it would appear when looking down on top of it.

PLANKTON PLANKTON

(1) Small, usually microscopic, plants (phytoplankton) and animals (zooplankton) in aquatic systems.

(2) All of the smaller floating, suspended or self-propelled organisms in a body of water.

PLUG FLOW PLUG FLOW

A type of flow that occurs in tanks, basins or reactors when a slug of water moves through a tank without ever dispersing or mixing with the rest of the water flowing through the tank.

PMCLs PMCLs

Primary **M**aximum **C**ontaminant **L**evels. Primary MCLs for various water quality indicators are established to protect public health.

POINT SOURCE POINT SOURCE

A discharge that comes out of the end of a pipe. A nonpoint source refers to runoff or a discharge from a field or similar source.

POLE SHADER POLE SHADER

A copper bar circling the laminated iron core inside the coil of a magnetic starter.

POLLUTION POLLUTION

The impairment (reduction) of water quality by agricultural, domestic, or industrial wastes (including thermal and atomic wastes), to a degree that has an adverse effect on any beneficial use of water.

POLYCHLORINATED BIPHENYLS POLYCHLORINATED BIPHENYLS

A class of organic compounds that cause adverse health effects in domestic water supplies.

POLYELECTROLYTE (POLLY-ee-LECK-tro-lite) POLYELECTROLYTE

A high-molecular-weight (relatively heavy) substance having points of positive or negative electrical charges that is formed by either natural or man-made processes. Natural polyelectrolytes may be of biological origin or derived from starch products and cellulose derivatives. Man-made polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. Often called a POLYMER.

POLYMER POLYMER

A chemical formed by the union of many monomers (a molecule of low molecular weight). Polymers are used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers, but not all polymers are polyelectrolytes.

PORE PORE

A very small open space in a rock or granular material. Also see INTERSTICE.

POROSITY POROSITY

(1) A measure of the spaces or voids in a material or aquifer.

(2) The ratio of the volume of spaces in a rock or soil to the total volume. This ratio is usually expressed as a percentage.

$$\text{Porosity, \%} = \frac{(\text{Volume of Spaces})(100\%)}{\text{Total Volume}}$$

POSITIVE BACTERIOLOGICAL SAMPLE POSITIVE BACTERIOLOGICAL SAMPLE

A water sample in which gas is produced by coliform organisms during incubation in the multiple tube fermentation test. See Chapter 11, Lab Procedures, "Coliform Test," for details.

POSITIVE DISPLACEMENT PUMP POSITIVE DISPLACEMENT PUMP

A type of piston, diaphragm, gear or screw pump that delivers a constant volume with each stroke. Positive displacement pumps are used as chemical solution feeders.

POSTCHLORINATION POSTCHLORINATION

The addition of chlorine to the plant effluent, *FOLLOWING* plant treatment, for disinfection purposes.

POTABLE WATER (POE-tuh-bull) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

POWER FACTOR POWER FACTOR

The ratio of the true power passing through an electric circuit to the product of the voltage and amperage in the circuit. This is a measure of the lag or load of the current with respect to the voltage.

PPM PPM

See PARTS PER MILLION.

PRECHLORINATION PRECHLORINATION

The addition of chlorine at the headworks of the plant *PRIOR TO* other treatment processes mainly for disinfection and control of tastes, odors and aquatic growths. Also applied to aid in coagulation and settling.

PRECIPITATE (pre-SIP-uh-TATE) PRECIPITATE

(1) An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

(2) The separation from solution of an insoluble substance.

PRECIPITATION (pre-SIP-uh-TAY-shun) PRECIPITATION

(1) The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail, or other forms of moisture.

(2) The chemical transformation of a substance in solution into an insoluble form (precipitate).

PRECISION PRECISION

The ability of an instrument to measure a process variable and to repeatedly obtain the same result. The ability of an instrument to reproduce the same results.

PRECURSOR, THM (pre-CURSE-or) PRECURSOR, THM

Natural organic compounds found in all surface and groundwaters. These compounds *MAY* react with halogens (such as chlorine) to form trihalomethanes (try-HAL-o-METH-hanes) (THMs); they *MUST* be present in order for THMs to form.

PRESCRIPTIVE (pre-SKRIP-tive) PRESCRIPTIVE

Water rights which are acquired by diverting water and putting it to use in accordance with specified procedures. These procedures include filing a request to use unused water in a stream, river or lake with a state agency.

PRESSURE CONTROL PRESSURE CONTROL

A switch which operates on changes in pressure. Usually this is a diaphragm pressing against a spring. When the force on the diaphragm overcomes the spring pressure, the switch is actuated (activated).

PRESSURE HEAD PRESSURE HEAD

The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

PRESTRESSED PRESTRESSED

A prestressed pipe has been reinforced with wire strands (which are under tension) to give the pipe an active resistance to loads or pressures on it.

PRIMARY ELEMENT PRIMARY ELEMENT

An instrument which measures (senses) a physical condition or variable of interest. Floats and thermocouples are examples of primary elements. Also called a SENSOR.

PRIME PRIME

The action of filling a pump casing with water to remove the air. Most pumps must be primed before startup or they will not pump any water.

PROCESS VARIABLE PROCESS VARIABLE

A physical or chemical quantity which is usually measured and controlled in the operation of a water treatment plant or an industrial plant.

PRODUCT WATER PRODUCT WATER

Water that has passed through a water treatment plant. All the treatment processes are completed or finished. This water is the product from the water treatment plant and is ready to be delivered to the consumers. Also called FINISHED WATER.

PROFILE PROFILE

A drawing showing elevation plotted against distance, such as the vertical section or side view of a pipeline.

PRUSSIAN BLUE PRUSSIAN BLUE

A blue paste or liquid (often on a paper like carbon paper) used to show a contact area. Used to determine if gate valve seats fit properly.

PSIG PSIG

Pounds per **S**quare **I**nch **G**age pressure. The pressure within a closed container or pipe measured with a gage in pounds per square inch. See GAGE PRESSURE.

PUMPING WATER LEVEL PUMPING WATER LEVEL

The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is being drawn from the pool.

PURVEYOR, WATER (purr-VAY-or) PURVEYOR, WATER

An agency or person that supplies water (usually potable water).

PUTREFACTION (PEW-truh-FACK-shun) PUTREFACTION

Biological decomposition of organic matter, with the production of ill-smelling and tasting products, associated with anaerobic (no oxygen present) conditions.

QUICKLIME QUICKLIME

A material that is mostly calcium oxide (CaO) or calcium oxide in natural association with a lesser amount of magnesium oxide. Quicklime is capable of combining with water, that is, becoming slaked. Also see HYDRATED LIME.

RADIAL TO IMPELLER RADIAL TO IMPELLER

Perpendicular to the impeller shaft. Material being pumped flows at a right angle to the impeller.

RADICAL RADICAL

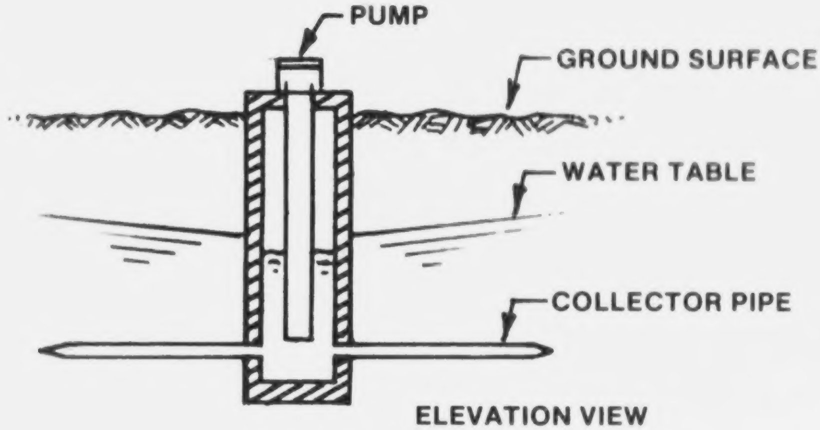
A group of atoms that is capable of remaining unchanged during a series of chemical reactions. Such combinations (radicals) exist in the molecules of many organic compounds; sulfate (SO_4^{2-}) is an inorganic radical.

RANGE RANGE

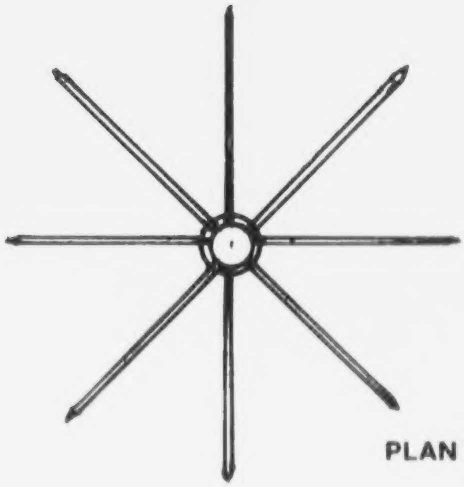
The spread from minimum to maximum values that an instrument is designed to measure. Also see SPAN and EFFECTIVE RANGE.

RANNEY COLLECTOR RANNEY COLLECTOR

This water collector is constructed as a dug well from 12 to 16 feet (3.5 to 5 m) in diameter that has been sunk as a caisson near the bank of a river or lake. Screens are driven radially and approximately horizontally from this well into the sand and the gravel deposits underlying the river.



ELEVATION VIEW



PLAN VIEW OF COLLECTOR PIPES

RANNEY COLLECTOR

RAW WATER RAW WATER

(1) Water in its natural state, prior to any treatment.

(2) Usually the water entering the first treatment process of a water treatment plant.

REAERATION (RE-air-A-shun) REAERATION

The introduction of air through forced air diffusers into the lower layers of the reservoir. As the air bubbles form and rise through the water, oxygen from the air dissolves into the water and replenishes the dissolved oxygen. The rising bubbles also cause the lower waters to rise to the surface where oxygen from the atmosphere is transferred to the water. This is sometimes called surface reaeration.

REAGENT (re-A-gent) REAGENT

A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances.

RECARBONATION (re-CAR-bun-NAY-shun) RECARBONATION

A process in which carbon dioxide is bubbled into the water being treated to lower the pH. The pH may also be lowered by the addition of acid. Recarbonation is the final stage in the lime-soda ash softening process. This process converts carbonate ions to bicarbonate ions and stabilizes the solution against the precipitation of carbonate compounds.

RECEIVER RECEIVER

A device which indicates the result of a measurement. Most receivers in the water utility field use either a fixed scale and movable indicator (pointer) such as pressure gage or a movable scale and movable indicator like those used on a circular-flow recording chart. Also called an INDICATOR.

RECORDER RECORDER

A device that creates a permanent record, on a paper chart or magnetic tape, of the changes of some measured variable.

REDUCING AGENT REDUCING AGENT

Any substance, such as base metal (iron) or the sulfide ion (S^{2-}) that will readily donate (give up) electrons. The opposite is an OXIDIZING AGENT.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions (no dissolved oxygen present), sulfur compounds are reduced to odor-producing hydrogen sulfide (H_2S) and other compounds. The opposite of OXIDATION.

REFERENCE REFERENCE

A physical or chemical quantity whose value is known exactly, and thus is used to calibrate or standardize instruments.

RELIQUEFACTION (re-LICK-we-FACK-shun) RELIQUEFACTION

The return of a gas to the liquid state; for example, a condensation of chlorine gas to return it to its liquid form by cooling.

REPRESENTATIVE SAMPLE REPRESENTATIVE SAMPLE

A portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of material or water being sampled.

RESIDUAL CHLORINE RESIDUAL CHLORINE

The amount of free and/or available chlorine remaining after a given contact time under specified conditions.

RESIDUE RESIDUE

The dry solids remaining after the evaporation of a sample of water or sludge. Also see TOTAL DISSOLVED SOLIDS.

RESPIRATION RESPIRATION

The process in which an organism uses oxygen for its life processes and gives off carbon dioxide.

REVERSE OSMOSIS (oz-MOE-sis) REVERSE OSMOSIS

The application of pressure to a concentrated solution which causes the passage of a liquid from the concentrated solution to a weaker solution across a semipermeable membrane. The membrane allows the passage of the solvent (water) but not the dissolved solids (solutes). The liquid produced is a demineralized water. Also see OSMOSIS.

RIPARIAN (ri-PAIR-ee-an) RIPARIAN

Water rights which are acquired together with title to the land bordering a source of surface water. The right to put to beneficial use surface water adjacent to your land.

RODENTICIDE (row-DENT-uh-SIDE) RODENTICIDE

Any substance or chemical used to kill or control rodents.

ROTAMETER (RODE-uh-ME-ter) ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a tapered, calibrated tube. Inside the tube is a small ball or bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind or on the tube by looking at the middle of the ball or at the widest part or top of the float.

ROTOR ROTOR

The rotating part of a machine. The rotor is surrounded by the stationary (non-moving) parts (stator) of the machine.

SACRIFICIAL ANODE SACRIFICIAL ANODE

An easily corroded material deliberately installed in a pipe or tank. The intent of such an installation is to give up (sacrifice) this anode to corrosion while the water supply facilities remain relatively corrosion free.

SAFE DRINKING WATER ACT SAFE DRINKING WATER ACT

Commonly referred to as SDWA. An Act passed by the U.S. Congress in 1974. The Act establishes a cooperative program among local, state and federal agencies to insure safe drinking water for consumers.

SAFE WATER SAFE WATER

Water that does not contain harmful bacteria, or toxic materials or chemicals. Water may have taste and odor problems, color and certain mineral problems and still be considered safe for drinking.

SAFE YIELD SAFE YIELD

The annual quantity of water that can be taken from a source of supply over a period of years without depleting the source permanently (beyond its ability to be replenished naturally in "wet years").

SALINITY SALINITY

(1) The relative concentration of dissolved salts, usualy sodium chloride, in a given water.

(2) A measure of the concentration of dissolved mineral substances in water.

SANITARY SURVEY SANITARY SURVEY

A detailed evaluation and/or inspection of a source of water supply and all conveyances, storage, treatment and distribution facilities to insure its protection from all pollution sources.

SAPROPHYTES (SAP-row-FIGHTS) SAPROPHYTES

Organisms living on dead or decaying organic matter. They help natural decomposition of organic matter in water.

SATURATION SATURATION

The condition of a liquid (water) when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

SATURATOR (SAT-you-RAY-tore) SATURATOR

A device which produces a fluoride solution for the fluoridation process. The device is usually a cylindrical container with granular sodium fluoride on the bottom. Water flows either upward or downward through the sodium fluoride to produce the fluoride solution.

SCFM SCFM

Cubic **F**eet of air per **M**inute at **S**tandard conditions of temperature, pressure and humidity (0°C / 14.7 psia / 50% relative humidity).

SDWA SDWA

See **S**AFE **D**RINKING **W**ATER **A**CT.

SCHEDULE, PIPE SCHEDULE, PIPE

A sizing system of arbitrary numbers that specifies the I.D. (inside diameter) and O.D. (outside diameter) for each diameter pipe. This term is used for steel, wrought iron and some types of plastic pipe. Also used to describe the strength of some types of plastic pipe.

SECCHI DISC (SECK-key) SECCHI DISC

A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded Secchi disc transparency.

SEDIMENTATION (SED-uh-men-TAY-shun) SEDIMENTATION

A water treatment process in which solid particles settle out of the water being treated in a large clarifier or sedimentation basin.

SEIZE UP SEIZE UP

Seize up occurs when an engine overheats and a part expands to the point where the engine will not run. Also called "freezing."

SENSOR SENSOR

An instrument that measure (senses) a physical condition or variable of interest. Floats and thermocouples are examples of sensors. Also called a PRIMARY ELEMENT.

SEPTIC (SEP-tick) SEPTIC

A condition produced by bacteria when all oxygen supplies are depleted. If severe, bottom deposits and water turn black, give off foul odors, and the water has a greatly increased chlorine demand.

SEQUESTRATION (SEE-kwes-TRAY-shun) SEQUESTRATION

A chemical complexing (forming or joining together) of metallic cations (such as iron) with certain inorganic compounds, such as phosphate. Sequestration prevents the precipitation of the metals (iron). Also see CHELATION.

SERVICE PIPE SERVICE PIPE

The pipeline extending from the water main to the building served or to the consumer's system.

SET POINT SET POINT

The position at which the control or controller is set. This is the same as the desired value of the process variable.

SEWAGE SEWAGE

The used water and solids that flow from homes through sewers to a wastewater treatment plant. The preferred term is WASTEWATER.

SHOCK LOAD SHOCK LOAD

The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity, or other pollutants.

SHORT-CIRCUITING SHORT-CIRCUITING

A condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction, or settling times in comparison with the theoretical (calculated) or presumed detention times.

SIMULATE SIMULATE

To reproduce the action of some process, usually on a smaller scale.

SINGLE-STAGE PUMP SINGLE-STAGE PUMP

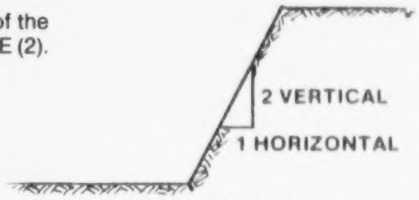
A pump that has only one impeller. A multi-stage pump has more than one impeller.

SLAKE SLAKE

To mix with water with a true chemical combination (hydrolysis) taking place, such as in the slaking of lime.

SLOPE SLOPE

The slope or inclination of a trench bottom or a trench side wall is the ratio of the vertical distance to the horizontal distance or "rise over run." Also see GRADE (2).



2:1 SLOPE

SLUDGE (sluj) SLUDGE

The settleable solids separated from water during processing.

SLURRY (SLUR-e) SLURRY

A watery mixture or suspension of insoluble (not dissolved) matter; a thin watery mud or any substance resembling it (such as a grit slurry or a lime slurry).

SMCLs SMCLs

Secondary **M**aximum **C**ontaminant **L**evel**s**. Secondary MCLs for various water quality indicators are established to protect public welfare.

SNARL SNARL

Suggested **N**o **A**dverse **R**esponse **L**evel. The concentration of a chemical in water that is expected not to cause an adverse health effect.

SOFTWARE PROGRAMS SOFTWARE PROGRAMS

Computer programs; the list of instructions that tell a computer how to perform a given task or tasks.

SOFT WATER SOFT WATER

Water having a low concentration of calcium and magnesium ions. According to U.S. Geological Survey guidelines, soft water is water having a hardness of 60 milligrams per liter or less.

SOLENOID (SO-luh-noid) SOLENOID

A magnetically (electrical coil) operated mechanical device. Solenoids can operate a small valve or a larger switch.

SOLUTION SOLUTION

A liquid mixture of dissolved substances. In a solution it is impossible to see all the separate parts.

SOUNDING TUBE SOUNDING TUBE

A pipe or tube used for measuring the depths of water.

SPAN SPAN

The scale or range of values an instrument is designed to measure. Also see RANGE.

SPECIFIC CONDUCTANCE SPECIFIC CONDUCTANCE

A rapid method of estimating the dissolved-solids content of a water supply. The measurement indicates the capacity of a sample of water to carry an electrical current, which is related to the concentration of ionized substances in the water. Also called CONDUCTANCE.

SPECIFIC GRAVITY SPECIFIC GRAVITY

Weight of a particle, substance, or chemical solution in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (39°F). Particulates in raw water may have a specific gravity of 1.005 to 2.5.

SPECIFIC YIELD SPECIFIC YIELD

The quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity. Specific yield may be expressed as a ratio or as a percentage by volume.

SPOIL SPOIL

Excavated material such as soil from the trench of a water main.

SPORE SPORE

The reproductive body of an organism which is capable of giving rise to a new organism either directly or indirectly. A viable (able to live and grow) body regarded as the resting stage of an organism. A spore is usually more resistant to disinfectants and heat than most organisms.

SPRING LINE SPRING LINE

Theoretical center of a pipeline. Also, the guideline for laying a course of bricks.

STALE WATER STALE WATER

Water which has not flowed recently and may have picked up tastes and odors from distribution lines or storage facilities.

STANDARD STANDARD

A physical or chemical quantity whose value is known exactly, and is used to calibrate or standardize instruments. Also see REFERENCE.

STANDARD METHODS STANDARD METHODS

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER. A joint publication of the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation which outlines the procedures used to analyze the impurities in water and wastewater.

STANDARD SOLUTION STANDARD SOLUTION

A solution in which the exact concentration of a chemical or compound is known.

STANDARDIZE STANDARDIZE

To compare with a standard.

(1) In wet chemistry, to find out the exact strength of a solution by comparing it with a standard of known strength.

(2) To set up an instrument or device to read a standard. This allows you to adjust the instrument so that it reads accurately, or enables you to apply a correction factor to the readings.

STARTERS STARTERS

Devices used to start up large motors gradually to avoid severe mechanical shock to a driven machine and to prevent disturbance to the electrical lines (causing dimming and flickering of lights).

STATIC HEAD STATIC HEAD

When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. (The static pressure in psi is the static head in feet times 0.433 psi/ft.) Also see DYNAMIC PRESSURE and STATIC PRESSURE.

STATIC PRESSURE STATIC PRESSURE

When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. The static pressure in psi is the static head in feet times 0.433 psi/ft. Also see DYNAMIC PRESSURE and STATIC HEAD.

STATIC WATER DEPTH STATIC WATER DEPTH

The vertical distance in feet from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.

STATIC WATER LEVEL STATIC WATER LEVEL

(1) The elevation or level of the water table in a well when the pump is not operating.

(2) The level or elevation to which water would rise in a tube connected to an artesian aquifer, or basin, or conduit under pressure.

STATOR STATOR

That portion of a machine which contains the stationary (non-moving) parts that surround the moving parts (rotor).

STERILIZATION (STARE-uh-luh-ZAY-shun) STERILIZATION

The removal or destruction of all microorganisms, including pathogenic and other bacteria, vegetative forms and spores. Compare with DISINFECTION.

STETHOSCOPE STETHOSCOPE

An instrument used to magnify sounds and convey them to the ear.

STRATIFICATION (STRAT-uh-fuh-KAY-shun) STRATIFICATION

The formation of separate layers (of temperature, plant, or animal life) in a lake or reservoir. Each layer has similar characteristics such as all water in the layer has the same temperature. Also see THERMAL STRATIFICATION.

SUBMERGENCE SUBMERGENCE

The distance between the water surface and the media surface in a filter.

SUBSIDENCE (sub-SIDE-ence) SUBSIDENCE

The dropping or lowering of the ground surface as a result of removing excess water (overdraft or over pumping) from an aquifer. After excess water has been removed, the soil will settle, become compacted and the ground surface will drop.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure [in feet (meters) of water or inches (centimeters) of mercury vacuum] on the suction side of the pump. The pressure can be measured from the centerline of the pump *DOWN TO* (lift) the elevation of the hydraulic grade line on the suction side of the pump.

SUPERCHLORINATION (SUE-per-KLOR-uh-NAY-shun) SUPERCHLORINATION

Chlorination with doses that are deliberately selected to produce free or combined residuals so large as to require dechlorination.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the water surface of a basin or container.

SUPERSATURATED SUPERSATURATED

An unstable condition of a solution (water) in which the solution contains a substance at a concentration greater than the saturation concentration for the substance.

SURFACE LOADING SURFACE LOADING

One of the guidelines for the design of settling tanks and clarifiers in treatment plants. Used by operators to determine if tanks and clarifiers are hydraulically (flow) over- or underloaded. Also called OVERFLOW RATE.

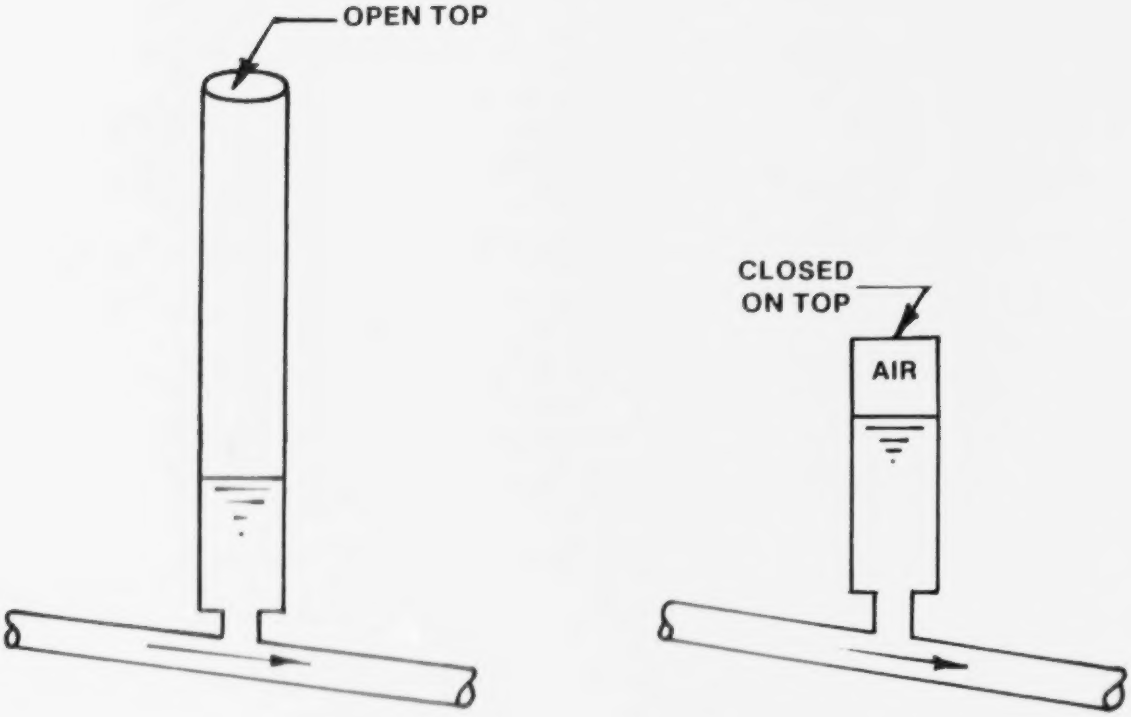
$$\text{Surface Loading, GPD/sq ft} = \frac{\text{Flow, gallon/day}}{\text{Surface Area, sq ft}}$$

SURFACTANT (sir-FAC-tent) SURFACTANT

Abbreviation for surface-active agent. The active agent in detergents that possesses a high cleaning ability.

SURGE CHAMBER SURGE CHAMBER

A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.



TYPES OF SURGE CHAMBERS

SURGE CHAMBER

SUSPENDED SOLIDS SUSPENDED SOLIDS

(1) Solids that either float on the surface or are suspended in water or other liquids, and which are largely removable by laboratory filtering.

(2) The quantity of material removed from water in a laboratory test, as prescribed in *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER* and referred to as nonfilterable residue.

TAILGATE SAFETY MEETING TAILGATE SAFETY MEETING

The term *TAILGATE* comes from the safety meetings regularly held by the construction industry around the tailgate of a truck.

TCE TCE

See **T**RI**C**HLORO**E**THANE.

TDS TDS

See **T**OTAL **D**ISSOLVED **S**OLIDS.

TELEMETRY (tel-LEM-uh-tree) TELEMETRY

The electrical link between the transmitter and the receiver. Telephone lines are commonly used to serve as the electrical line.

TEMPERATURE SENSOR TEMPERATURE SENSOR

A device that opens and closes a switch in response to changes in the temperature. This device might be a metal contact, or a thermocouple that generates minute electrical current proportional to the difference in heat, or a variable resistor whose value changes in response to changes in temperature. Also called a HEAT SENSOR.

THERMAL STRATIFICATION (STRAT-uh-fuh-KAY-shun) THERMAL STRATIFICATION

The formation of layers of different temperatures in a lake or reservoir. Also see STRATIFICATION.

THERMOCLINE (THUR-moe-KLINE) THERMOCLINE

The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. Also called the METALIMNION.

THERMOCOUPLE THERMOCOUPLE

A heat-sensing device made of two conductors of different metals joined at their ends. An electric current is produced when there is a difference in temperature between the ends.

THM THM

See **T**RI**H**ALO**M**ETHANES.

THM PRECURSOR THM PRECURSOR

See PRECURSOR, THM.

THRESHOLD ODOR THRESHOLD ODOR

The minimum odor of a water sample that can just be detected after successive dilutions with odorless water. Also called ODOR THRESHOLD.

THRESHOLD ODOR NUMBER THRESHOLD ODOR NUMBER

TON. The greatest dilution of a sample with odor-free water that still yields a just-detectable odor.

THRUST BLOCK THRUST BLOCK

A mass of concrete or similar material appropriately placed around a pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.

TIME LAG TIME LAG

The time required for processes and control systems to respond to a signal or to reach a desired level.

TIMER TIMER

A device for automatically starting or stopping a machine or other device at a given time.

TITRATE (TIE-trate) TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a certain color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical reagent in increments until completion of the reaction, as signaled by the end point.

TOPOGRAPHY TOPOGRAPHY

The arrangement of hills and valleys in a geographic area.

TOTAL DISSOLVED SOLIDS (TDS) TOTAL DISSOLVED SOLIDS (TDS)

All of the dissolved solids in a water. TDS is measured on a sample of water that has passed through a very fine mesh filter to remove suspended solids. The water passing through the filter is evaporated and the residue represents the dissolved solids. Also see SPECIFIC CONDUCTANCE.

TOTAL DYNAMIC HEAD (TDH) TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTAL RESIDUAL CHLORINE TOTAL RESIDUAL CHLORINE

The amount of available chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see RESIDUAL CHLORINE.

TOTALIZER TOTALIZER

A device or meter that continuously measures and calculates (adds) total flows in gallons, million gallons, cubic feet, or some other unit of volume measurement. Also called an INTEGRATOR.

TOXAPHENE (TOX-uh-FEEN) TOXAPHENE

A chemical that causes adverse health effects in domestic water supplies and also is toxic to freshwater and marine aquatic life.

TOXIC (TOX-ick) TOXIC

A substance which is poisonous to an organism.

TRANSDUCER (trans-DUE-sir) TRANSDUCER

A device which senses some varying condition and converts it to an electrical signal for transmission to some other device (a receiver) for processing or decision making.

TRANSMISSION LINES TRANSMISSION LINES

Pipelines that transport raw water from its source to a water treatment plant. After treatment, water is usually pumped into pipelines (transmission lines) that are connected to a distribution grid system.

TRANSMISSIVITY (TRANS-miss-SIV-it-tee) TRANSMISSIVITY

A measure of the ability to transmit (as in the ability of an aquifer to transmit water).

TRANSPIRATION (TRAN-spur-RAY-shun) TRANSPIRATION

The process by which water vapor is released to the atmosphere by living plants. This process is similar to people sweating. Also called EVAPOTRANSPIRATION.

TREMIE (TREH-me) TREMIE

A device used to place concrete or grout under water.

TRICHLOROETHANE (TCE) (try-KLOR-o-ETH-hane) TRICHLOROETHANE (TCE)

An organic chemical used as a cleaning solvent that causes adverse health effects in domestic water supplies.

TRIHALOMETHANES (tri-HAL-o-METH-hanes) TRIHALOMETHANES

Derivatives of methane, CH_4, in which three halogen atoms (chlorine or bromine) are substituted for three of the hydrogen atoms. Often formed during chlorination by reactions with natural organic materials in the water. The resulting compounds (THMs) are suspected of causing cancer.

TUBE SETTLER TUBE SETTLER

A device that uses bundles of small bore (2 to 3 inches or 50 to 75 mm) tubes installed on an incline as an aid to sedimentation. The tubes may come in a variety of shapes including circular and rectangular. As water rises within the tubes, settling solids fall to the tube surface. As the sludge (from the settled solids) in the tube gains weight, it moves down the tubes and settles to the bottom of the basin for removal by conventional sludge collection means. Tube settlers are sometimes installed in sedimentation basins and clarifiers to improve particle removal.

TUBERCLE (TOO-burr-cull) TUBERCLE

A protective crust of corrosion products (rust) which builds up over a pit caused by the loss of metal due to corrosion.

TUBERCULATION (too-BURR-que-LAY-shun) TUBERCULATION

The development of formation of small mounds of corrosion products (rust) on the inside of iron pipe. These mounds (tubercules) increase the roughness of the inside of the pipe thus increasing resistance to water flow (decreases the C Factor).

TURBID TURBID

Having a cloudy or muddy appearance.

TURBIDIMETER TURBIDIMETER

See TURBIDITY METER.

TURBIDITY (ter-BID-it-tee) TURBIDITY

The cloudy appearance of water caused by the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.

TURBIDITY METER TURBIDITY METER

An instrument for measuring and comparing the turbidity of liquids by passing light through them and determining how much light is reflected by the particles in the liquid.

TURBIDITY UNITS (TU) TURBIDITY UNITS (TU)

Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water. They are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.

TURN-DOWN RATIO TURN-DOWN RATIO

The ratio of the design range to the range of acceptable accuracy or precision of an instrument. Also see EFFECTIVE RANGE.

UNCONSOLIDATED FORMATION UNCONSOLIDATED FORMATION

A sediment that is loosely arranged or unstratified (not in layers) or whose particles are not cemented together (soft rock); occurring either at the ground surface or at a depth below the surface. Also see CONSOLIDATED FORMATION.

UNIFORMITY COEFFICIENT (U.C.) UNIFORMITY COEFFICIENT (U.C.)

The ratio of (1) the diameter of a grain (particle) of a size that is barely too large to pass through a sieve that allows 60 percent of the material (by weight) to pass through, to (2) the diameter of a grain (particle) of a size that is barely too large to pass through a sieve that allows 10 percent of the material (by weight) to pass through.

$$\text{Uniformity Coefficient} = \frac{\text{Particle Diameter}_{60\%}}{\text{Particle Diameter}_{10\%}}$$

VARIABLE FREQUENCY DRIVE VARIABLE FREQUENCY DRIVE

A control system that allows the frequency of the current applied to a motor to be varied. The motor is connected to a low-frequency source while standing still; the frequency is then increased gradually until the motor and pump (or other driven machine) is at the desired speed.

VARIABLE, MEASURED VARIABLE, MEASURED

A factor (flow, temperature) that is sensed and quantified (reduced to a reading of some kind) by a primary element or sensor.

VARIABLE, PROCESS VARIABLE, PROCESS

A physical or chemical quantity which is usually measured and controlled in the operation of a water treatment plant or an industrial plant.

VELOCITY HEAD VELOCITY HEAD

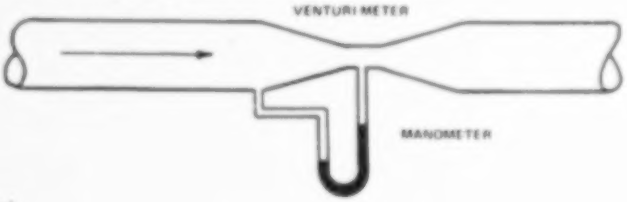
The energy in flowing water as determined by a vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

VENTURI METER VENTURI METER

A flow measuring device placed in a pipe. The device consists of a tube whose diameter gradually decreases to a throat and then gradually expands to the diameter of the pipe. The flow is determined on the basis of the differences in pressure (caused by different velocity heads) between the entrance and throat of the Venturi meter.

[SEE DRAWING ON PAGE 485]

NOTE: Most Venturi meters have pressure sensing taps rather than a manometer to measure the pressure difference. The upstream tap is the high pressure tap or side of the monometer.



VISCOSITY (vis-KOSS-uh-tee) VISCOSITY

A property of water, or any other fluid, which resists efforts to change its shape or flow. Syrup is more viscous (has a higher viscosity) than water. The viscosity of water increases significantly as temperatures decrease. Motor oil is rated by how thick (viscous) it is; 20 weight oil is considered relatively thin while 50 weight oil is relatively thick or viscous.

VOID VOID

A pore or open space in rock, soil or other granular material, not occupied by solid matter. The pore or open space may be occupied by air, water, or other gaseous or liquid material. Also called a void space or interstice.

VOLATILE (VOL-uh-tull) VOLATILE

A substance that is capable of being evaporated or easily changed to a vapor at relatively low temperatures. For example, gasoline is a highly volatile liquid.

VOLATILE ACIDS VOLATILE ACIDS

Acids produced during digestion. Fatty acids which are soluble in water and can be steam-distilled at atmospheric pressure. Also called "organic acids." Volatile acids are commonly reported as equivalent to acetic acid.

VOLATILE LIQUIDS VOLATILE LIQUIDS

Liquids which easily vaporize or evaporate at room temperatures.

VOLATILE SOLIDS VOLATILE SOLIDS

Those solids in water or other liquids that are lost on ignition of the dry solids at 550°C.

VOLTAGE VOLTAGE

The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. See ELECTROMOTIVE FORCE (E.M.F.).

VOLUMETRIC VOLUMETRIC

A measurement based on the volume of some factor. Volumetric titration is a means of measuring unknown concentrations of water quality indicators in a sample by determining the volume of titrant or liquid reagent needed to complete particular reactions.

VORTEX VORTEX

A revolving mass of water which forms a whirlpool. This whirlpool is caused by water flowing out of a small opening in the bottom of a basin or reservoir. A funnel-shaped opening is created downward from the water surface.

WASTEWATER WASTEWATER

The used water and solids from a community (including used water from industrial processes) that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WATER AUDIT WATER AUDIT

A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

WATER PURVEYOR (purr-VAY-or) WATER PURVEYOR

An agency or person that supplies water (usually potable water).

WATER TABLE WATER TABLE

The upper surface of the zone of saturation of groundwater in an unconfined aquifer.

WATT WATT

A unit of power equal to one joule per second. The power of a current of one ampere flowing across a potential difference of one volt.

WEIR (weer) WEIR

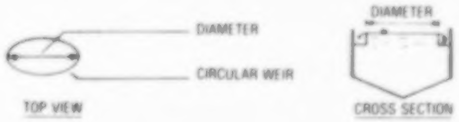
(1) A wall or plate placed in an open channel and used to measure the flow of water. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used.

(2) A wall or obstruction used to control flow (from settling tanks and clarifiers) to assure uniform flow rate and avoid short-circuiting.

WEIR DIAMETER (weer) WEIR DIAMETER

Many circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. The diameter of the weir is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.

WEIR DIAMETER



WEIR LOADING WEIR LOADING

A guideline used to determine the length of weir needed on settling tanks and clarifiers in treatment plants. Used by operators to determine if weirs are hydraulically (flow) overloaded.

$$\text{Weir Loading, GPM/ft} = \frac{\text{Flow, GPM}}{\text{Length of Weir, ft}}$$

WELL LOG WELL LOG

A record of the thickness and characteristics of the soil, rock and water-bearing formations encountered during the drilling (sinking) of a well.

WET CHEMISTRY WET CHEMISTRY

Laboratory procedures used to analyze a sample of water using liquid chemical solutions (wet) instead of, or in addition to, laboratory instruments.

WHOLESOME WATER WHOLESOME WATER

A water that is safe and palatable for human consumption.

WIRE-TO-WATER EFFICIENCY WIRE-TO-WATER EFFICIENCY

The efficiency of a pump and motor together. Also called the OVERALL EFFICIENCY.

YIELD YIELD

The quantity of water (expressed as a rate of flow — GPM, GPH, GPD, or total quantity per year) that can be collected for a given use from surface or groundwater sources. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. Also see SAFE YIELD.

ZEOLITE ZEOLITE

A type of ion exchange material used to soften water. Natural zeolites are siliceous compounds (made of silica) which remove calcium and magnesium from hard water and replace them with sodium. Synthetic or organic zeolites are ion exchange materials which remove calcium or magnesium and replace them with either sodium or hydrogen.

ZETA POTENTIAL ZETA POTENTIAL

In coagulation and flocculation procedures, the difference in the electrical charge between the dense layer of ions surrounding the particle and the charge of the bulk of the suspended fluid surrounding this particle. The zeta potential is usually measured in millivolts.

ZONE OF AERATION ZONE OF AERATION

The comparatively dry soil or rock located between the ground surface and the top of the water table.

ZONE OF SATURATION ZONE OF SATURATION

The soil or rock located below the top of the groundwater table. By definition, the zone of saturation is saturated with water. Also see WATER TABLE.

ZOOPLANKTON (ZOE-PLANK-ton) ZOOPLANKTON

Small, usually microscopic animals (such as protozoans), found in lakes and reservoirs.

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X, Y & Z

No listings

INTERIM PRIMARY DRINKING WATER REGULATIONS

INORGANIC CHEMICALS	ARSENIC	0.05 mg/l	FOR ALL INORGANIC CONTAMINANTS LISTED SURFACE WATERS EVERY YEAR GROUNDWATERS EVERY 3 YEARS	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN: (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED. (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD, WHICHEVER IS SHORTER.	FOR ALL INORGANIC CONTAMINANTS LISTED EXCEPT NITRATE IF ANY CONTAMINANT EXCEEDS THE MCL, THIS MUST BE REPORTED TO THE STATE WITHIN 7 DAYS AND THREE ADDITIONAL SAMPLES (CALLED CHECK SAMPLES) MUST BE TAKEN WITHIN ONE MONTH	FOR ALL INORGANIC CONTAMINANTS LISTED EXCEPT NITRATE NOTIFY STATE WITHIN 7 DAYS IF MCL IS EXCEEDED AND INITIATE CHECK SAMPLING. WHEN THE AVERAGE OF THE ORIGINAL AND THREE ADDITIONAL CHECK SAMPLES STILL EXCEEDS THE MCL, THIS MUST BE REPORTED TO THE STATE WITHIN 48 HRS	FOR ALL INORGANIC CONTAMINANTS LISTED EXCEPT NITRATE WHEN THE AVERAGE OF THE ORIGINAL AND THREE ADDITIONAL CHECK SAMPLES EXCEEDS THE MCL, THE PUBLIC MUST BE NOTIFIED
	BARIUM	1 mg/l					
	CADMIUM	0.010 mg/l					
	CHROMIUM	0.05 mg/l					
	LEAD	0.05 mg/l					
	MERCURY	0.002 mg/l					
	SELENIUM	0.01 mg/l					
	SILVER	0.05 mg/l					
	SODIUM						
	FLUORIDE (AVERAGE ANNUAL AIR TEMPERATURES) — °F a 53.7 & BELOW b 53.8-58.3 c 58.4-63.8 d 63.9-70.6 e 70.7-79.2 f 79.3-90.5	a 2.4 mg/l b 2.2 mg/l c 2.0 mg/l d 1.8 mg/l e 1.6 mg/l f 1.4 mg/l					
	NITRATE (AS N)	10 mg/l			FOR NITRATE ONLY: WHEN THE CONCENTRATION EXCEEDS THE MCL, A CHECK SAMPLE MUST BE TAKEN WITHIN 24 HRS	FOR NITRATE ONLY IF THE AVERAGE OF THE ORIGINAL SAMPLE AND THE CHECK SAMPLE EXCEEDS THE MCL, REPORT TO THE STATE WITHIN 48 HRS	FOR NITRATE ONLY WHEN THE AVERAGE OF THE ORIGINAL AND THE CHECK SAMPLE EXCEEDS THE MCL, THE PUBLIC MUST BE NOTIFIED
ORGANIC CHEMICALS	CHLORINATED HYDROCARBONS PESTICIDES		SURFACE WATERS EVERY 3 YEARS STATE OPTION FOR GROUNDWATERS	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN: (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED. (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD, WHICHEVER IS SHORTER.	ANY CONTAMINANT EXCEEDING MCL MUST BE REPORTED TO STATE WITHIN 7 DAYS AND THREE ADDITIONAL (CHECK) SAMPLES TO BE TAKEN WITHIN ONE MONTH	WHEN THE AVERAGE OF THE ORIGINAL AND THREE ADDITIONAL CHECK SAMPLES STILL EXCEEDS THE MCL, THIS MUST BE REPORTED TO THE STATE WITHIN 48 HRS	WHEN THE AVERAGE OF THE ORIGINAL AND THREE ADDITIONAL CHECK SAMPLES STILL EXCEEDS THE MCL, THE PUBLIC MUST BE NOTIFIED
	ENDRIN	0.0002 mg/l					
	LINDANE	0.004 mg/l					
	METHOXYCHLOR	0.1 mg/l					
	TOXAPHENE	0.005 mg/l					
	CHLOROPHENOXYS HERBICIDES						
	2,4,5-TP (SILVEX) 2,4-D	0.01 mg/l 0.1 mg/l					
	TOTAL TRIHALOMETHANES	0.10 mg/l	QUARTERLY CHLORINATED SURFACE AND GROUNDWATERS	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF	AT LEAST ONE CHECK SAMPLE TO CONFIRM RESULTS OF REDUCED MONITERING SAMPLING VIOLATION	WHEN RUNNING ANNUAL AVERAGE EXCEEDS MCL REPORT TO STATE WITHIN 48 HRS	AVERAGE OF ANY 12 MO. WHICH EXCEEDS MCL MUST NOTIFY PUBLIC

TURBIDITY	TURBIDITY	1 TU MONTHLY AVERAGE (5 TU MONTHLY AVERAGE MAY APPLY AT STATE OPTION PROVIDED IT DOES NOT INTERFERE WITH 1 DISINFECTION 2 MAINTENANCE OF EFFECTIVE Cl_2 RESIDUAL 3 BACTERIOLOGICAL TESTS) OR 5 TU AVG. OF 2 CONSECUTIVE DAYS	SAMPLE SURFACE WATERS DAILY	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD WHICHEVER IS SHORTER	IF A TURBIDITY SAMPLE EXCEEDS 1 TU CHECK SAMPLE WITHIN 1 HR. IF CHECK SAMPLE CONFIRMS THE MCL IS EXCEEDED REPORT TO THE STATE WITHIN 48 HRS	USING THE CHECK SAMPLE TO CALCULATE AN AVERAGE. IF THE MONTHLY AVERAGE OF 1 TU OR 2 DAY AVERAGE OF 5 TU IS EXCEEDED, REPORT TO THE STATE WITHIN 48 HRS	WHEN MONTHLY AVERAGE 1 TU OR 2 DAY AVERAGE OF 5 TU IS EXCEEDED THE PUBLIC MUST BE NOTIFIED
MICRO-BIOLOGICAL CONTAMINANTS	COLIFORM BACTERIA	MEMBRANE FILTER COLIFORM SHALL NOT EXCEED 1 PER 100 ml FOR THE AVERAGE OF ALL MONTHLY SAMPLES, OR 4 PER 100 ml IN MORE THAN ONE SAMPLE IF LESS THAN 20 SAMPLES COLLECTED PER MONTH, OR 4 PER 100 ml IN MORE THAN 5% OF SAMPLES IF 20 OR MORE SAMPLES EXAMINED PER MONTH FERMENTATION TUBE — 10 ml PORTION* COLIFORMS SHALL NOT BE PRESENT IN MORE THAN 10% OF PORTIONS PER MONTH. NOT MORE THAN 1 SAMPLE MAY HAVE 3 OR MORE PORTIONS POSITIVE WHEN LESS THAN 20 SAMPLES ARE EXAMINED PER MONTH OR NOT MORE THAN 5% OF SAMPLES MAY HAVE 3 OR MORE PORTIONS POSITIVE WHEN 20 OR MORE SAMPLES ARE EXAMINED PER MONTH *IF 100 ml PORTIONS ARE USED SEE REGULATIONS, PAGE 59571	THE TOTAL NUMBER OF SAMPLES ARE BASED ON THE POPULATION TABLE FOR EXAMPLE ** POPULATION SERVED — MINIMUM NUMBER OF SAMPLES PER MONTH 25 to 1 000 — 1 1 001 to 2 500 — 2 2 501 to 3 300 — 3 ** THE ENTIRE POPULATION TABLE IS IN THE MANUAL CHLORINE RESIDUAL SUBSTITUTION • STATE APPROVAL • 75% OF THE REQUIRED COLIFORM TESTS MAY BE SUBSTITUTED • FOR EACH COLIFORM TEST TO BE SUBSTITUTED 4 Cl_2 RESIDUAL TESTS MUST BE CONDUCTED BUT AT LEAST 1 Cl_2 TEST PER DAY • MINIMUM FREE RESIDUAL 0.2 mg/L • METHOD DPD	MUST BE FOLLOWED BY TWO CONSECUTIVE NEGATIVE CHECK SAMPLES UNDER CERTAIN CONDITIONS A SYSTEM TAKING 10 OR FEWER SAMPLES MAY EXCLUDE ONE POSITIVE ROUTINE FROM CALCULATIONS REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD WHICHEVER IS SHORTER	MEMBRANE FILTER IF A SINGLE SAMPLE EXCEEDS 4 PER 100 ml, INITIATE AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES FROM SAME SAMPLING POINT. COLLECT ADDITIONAL SAMPLES DAILY OR AS DIRECTED BY THE STATE UNTIL AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES SHOW LESS THAN 1 PER 100 ml FERMENTATION TUBE - 10 ml PORTION* IF A SINGLE SAMPLE CONTAINS COLIFORM IN 3 OR MORE 10 ml PORTIONS INITIATE CHECK SAMPLING AS ABOVE AND CONTINUE UNTIL AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES SHOW NO POSITIVE TUBES *IF 100 ml PORTIONS ARE USED SEE REGULATIONS, PAGE 59571	MEMBRANE FILTER IF ANY MCL IS EXCEEDED, THE STATE MUST BE NOTIFIED IN 48 HRS. IF ANY CHECK SAMPLE CONFIRMS THE PRESENCE OF COLIFORM REPORT TO THE STATE WITHIN 48 HRS FERMENTATION TUBE IF ANY MCL IS EXCEEDED, THE STATE MUST BE NOTIFIED IN 48 HRS. IF ANY CHECK SAMPLE CONFIRMS THE PRESENCE OF COLIFORM REPORT TO THE STATE WITHIN 48 HRS CHLORINE RESIDUAL SUBSTITUTION IF DEFICIENT RESIDUAL IS CONFIRMED REPORT TO STATE WITHIN 48 HRS AND COLLECT COLIFORM BACTERIA SAMPLE WITHIN 1 HR. REPORT BACTERIAL RESULTS TO STATE WITHIN 48 HRS. OF COMPLETION OF ANALYSIS	IF ANY MCL IS EXCEEDED THE PUBLIC MUST BE NOTIFIED PUBLIC NOTICE DOES NOT APPLY TO DEFICIENT CHLORINE RESIDUAL SINCE THE RESIDUAL IS NOT A MAXIMUM CONTAMINANT LEVEL
RADIOLOGICAL CONTAMINANTS	NATURAL GROSS ALPHA COMBINED Ra 226 AND Ra 228 MAN MADE GROSS BETA ACTIVITY TRITIUM STRONTIUM 90	NATURAL SCREENING IF GROSS ALPHA EXCEEDS 5 pCi/L THEN TEST FOR Ra 226 IF Ra226 EXCEEDS 3pCi/L TEST FOR Ra228 Ra226 + Ra228 5pCi/L MAN MADE GROSS BETA 50pCi/L TRITIUM 20,000 pCi/L STRONTIUM 90 8 pCi/L	EVERY 4 YEARS (COMPLIANCE WITH MCL BASED ON AVERAGE OF ANALYSIS OF FOUR CONSECUTIVE QUARTERS)	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD, WHICHEVER IS SHORTER	STATE OPTION STATE OPTION	WHEN THE ANNUAL AVERAGE MCL IS EXCEEDED. THIS MUST BE REPORTED TO THE STATE WITHIN 48 HRS	WHEN THE AVERAGE OF THE ORIGINAL EXCEEDS THE MCL, THE PUBLIC MUST BE NOTIFIED IN A MANNER ACCEPTABLE TO THE STATE
INORGANIC CHEMICALS	NITRATE (AS N)	10 mg/L MAY ALLOW UP TO 20 mg/L UNDER CONDITIONS WHERE NO ADVERSE HEALTH EFFECTS WILL RESULT	STATE OPTION	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD, WHICHEVER IS SHORTER	WHEN THE CONCENTRATION EXCEEDS THE MCL, A CHECK SAMPLE MUST BE TAKEN WITHIN 24 HRS	IF THE AVERAGE OF THE ORIGINAL SAMPLE AND THE CHECK SAMPLE EXCEEDS THE MCL, REPORT TO THE STATE WITHIN 48 HRS	WHEN THE AVERAGE OF THE ORIGINAL AND THE CHECK SAMPLE EXCEEDS THE MCL, THE PUBLIC MUST BE NOTIFIED IN A MANNER ACCEPTABLE TO THE STATE
TURBIDITY	TURBIDITY	STATE OPTION A. 1 TU MONTHLY AVERAGE (5 TU MONTHLY AVERAGE MAY APPLY AT STATE OPTION PROVIDED IT DOES NOT INTERFERE WITH 1 DISINFECTION 2 MAINTENANCE OF EFFECTIVE Cl_2 RESIDUAL 3 BACTERIOLOGICAL TESTS) OR B. 5 TU AVG. OF 2 CONSECUTIVE DAYS	SAMPLE SURFACE WATERS DAILY	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD WHICHEVER IS SHORTER	IF A TURBIDITY SAMPLE EXCEEDS 1 TU CHECK SAMPLE WITHIN 1 HR. IF CHECK SAMPLE CONFIRMS THE MCL IS EXCEEDED REPORT TO THE STATE WITHIN 48 HRS	USING THE CHECK SAMPLE TO CALCULATE AN AVERAGE. IF THE MONTHLY AVERAGE OF 1 TU OR 2 DAY AVERAGE OF 5 TU IS EXCEEDED REPORT TO THE STATE WITHIN 48 HRS	IF THE MONTHLY AVERAGE OF 1 TU OR THE 2 DAY AVERAGE OF 5 TU IS EXCEEDED THE PUBLIC MUST BE NOTIFIED IN A MANNER ACCEPTABLE TO THE STATE
MICRO-BIOLOGICAL CONTAMINANTS	COLIFORM BACTERIA	MEMBRANE FILTER COLIFORM SHALL NOT EXCEED 1 PER 100 ml FOR THE AVERAGE OF ALL MONTHLY SAMPLES, OR 4 PER 100 ml IN MORE THAN ONE SAMPLE IF LESS THAN 20 SAMPLES COLLECTED PER MONTH, OR 4 PER 100 ml IN MORE THAN 5% OF SAMPLES IF 20 OR MORE SAMPLES EXAMINED PER MONTH FERMENTATION TUBE — 10 ml PORTION* COLIFORMS SHALL NOT BE PRESENT IN MORE THAN 10% OF PORTIONS PER MONTH. NOT MORE THAN 1 SAMPLE MAY HAVE 3 OR MORE PORTIONS POSITIVE WHEN LESS THAN 20 SAMPLES ARE EXAMINED PER MONTH, OR NOT MORE THAN 5% OF SAMPLES MAY HAVE 3 OR MORE PORTIONS POSITIVE WHEN 20 OR MORE SAMPLES ARE EXAMINED PER MONTH *IF 100 ml PORTIONS ARE USED, SEE REGULATIONS, PAGE 59571	AT LEAST ONE SAMPLE PER QUARTER (THE STATE MAY SPECIFY AN ALTERNATE FREQUENCY ON THE BASIS OF A SANITARY SURVEY)	REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN (A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED (B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD WHICHEVER IS SHORTER	MEMBRANE FILTER IF A SINGLE SAMPLE EXCEEDS 4 PER 100 ml, INITIATE AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES FROM SAME SAMPLING POINT. COLLECT ADDITIONAL SAMPLES DAILY OR AS DIRECTED BY THE STATE UNTIL AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES SHOW LESS THAN 1 PER 100 ml FERMENTATION TUBE —10 ml PORTION* IF A SINGLE SAMPLE CONTAINS COLIFORM IN 3 OR MORE 10 ml PORTIONS INITIATE CHECK SAMPLING AS ABOVE AND CONTINUE UNTIL AT LEAST 2 CONSECUTIVE DAILY CHECK SAMPLES SHOW NO POSITIVE TUBES *IF 100 ml PORTIONS ARE USED SEE REGULATIONS, PAGE 59571	MEMBRANE FILTER IF ANY MCL IS EXCEEDED, THE STATE MUST BE NOTIFIED IN 48 HRS. IF ANY CHECK SAMPLE CONFIRMS THE PRESENCE OF COLIFORM REPORT TO THE STATE WITHIN 48 HRS FERMENTATION TUBE IF ANY MCL IS EXCEEDED, THE STATE MUST BE NOTIFIED IN 48 HRS. IF ANY CHECK SAMPLE CONFIRMS THE PRESENCE OF COLIFORM REPORT TO THE STATE WITHIN 48 HRS	IF ANY MCL IS EXCEEDED THE PUBLIC MUST BE NOTIFIED IN A MANNER ACCEPTABLE TO THE STATE IF ANY MCL IS EXCEEDED THE PUBLIC MUST BE NOTIFIED IN A MANNER ACCEPTABLE TO THE STATE

NOTE: CORROSIVITY MONITORING REQUIRED ACCORDING TO SECTION 141.42 OF NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

SECONDARY DRINKING WATER REGULATIONS (STATE OPTION)

NAME OF CONTAMINANT	SMCL
CHLORIDE	250 mg/L
COLOR	15 COLOR UNITS
COPPER	1 mg/L
FOAMING AGENTS	0.5 mg/L
IRON	0.3 mg/L
MANGANESE	0.05 mg/L
ODOR	3 THRESHOLD ODOR NUMBER
pH	6.5-8.5
SULFATE	250 mg/L
TOTAL DISSOLVED SOLIDS TDS	500 mg/L
ZINC	5 mg/L

MONITORING REQUIREMENTS ROUTINE SAMPLING AND TESTING

FOR ALL CONTAMINANTS LISTED

STATE MAY DIRECT MORE FREQUENT MONITORING OF SPECIFIC PARAMETERS

NO LESS FREQUENT THAN THE MONITORING PERFORMANCE FOR INORGANIC CHEMICALS CONTAMINANTS IN THE NIPDWR

RECOMMENDED ROUTINE REPORTING

REPORT RESULTS WITHIN 10 DAYS AFTER COMPLETION OF TEST OR WITHIN

(A) FIRST 10 DAYS FOLLOWING THE MONTH IN WHICH THE RESULT IS RECEIVED

(B) FIRST 10 DAYS FOLLOWING END OF THE REQUIRED MONITORING PERIOD WHICHEVER IS SHORTER

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WATER QUALITY REGULATIONS, BY TIM GANNON IN VOLUME II, WATER TREATMENT PLANT OPERATION PUBLISHED BY FOUNDATION OF CALIFORNIA STATE UNIVERSITY, SACRAMENTO, 6000 J STREET, SACRAMENTO, CALIFORNIA 95819

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